Superconducting power transmission; Toward a society without energy loss

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Since the Industrial Revolution, world energy consumption has continued to increase drastically.[1] A huge amount of fossil fuels is used to supply energy, and it causes various problems. For example, it is predicted that we will run out of petroleum and natural gas in this century,[2] and carbon dioxide emitted by consuming fossil fuel may affect the global environment. To solve these problems, we must use generated energy as efficiently as possible, in other words, reduce energy loss as much as possible. Loss in electric power transmission is an enormous energy loss in modern society, and therefore reduce that loss has a great impact on energy problems. In this essay, I will introduce superconducting power transmission technology as a possible solution to a problem about a loss in electric power transmission and consider its prospects.

Electric energy is widely used because of mainly two reasons. The first one is that it can be easily transformed into other forms of energy such as kinetic energy, heat energy, light energy, etc. The second one is that it can be transmitted continuously by only installing electric cables. For these reasons, generated electric power accounts for about 19% of the primary energy supply.[3] Considering the conversion efficiency of thermal power generation which is the commonest power generation system is about 30%-50%, about 40% of the primary energy supply is used to generate electric power.

In general, electric power is produced on large scale and intensively in power stations, transmitted over a long distance through the electrical grid, and finally consumed. Ideally, all the electric power produced is transmitted to consumption areas, but this is not the case. In reality, some part of electric power is converted into heat during transportation and dissipated. This is “the loss in electric power transmission”. One of the main causes of the loss in electric power transmission is the electrical resistivity of a material used as power lines. Thus, the loss can be reduced by using low resistance metal such as copper for power lines. However, even if we use copper for power lines, several percent of power is lost during transmission. This might seem negligible small, but because an enormous amount of electric power is generated as mentioned above, this small percent loss is also huge. Even when we consider only Japan, about 40 TWh electric power, which is 6 times larger than typical nuclear power station output is lost per one year as transmission loss.[3]

The loss in electric power transmission arises mainly from the electrical resistivity of power lines. Therefore, if we use materials without electrical resistivity, that loss can be reduced drastically. But is there such material? The answer is yes, and it is called a superconductor.

Superconductivity was first discovered in 1911 by Onnes, who was studying the electronic property of metal under low-temperature conditions. It was observed that the electrical resistance of mercury fell to zero when it was cooled below -269℃.[4] This zero-resistance state is called a superconducting state. In decades after Onnes's discovery, a superconducting state was observed in several other materials, for example, lead (below -266℃) and niobium carbide (below -263℃). At that time, applications of superconductors are strongly limited because Large-scale equipment or expensive cryogen such as liquid helium is needed to cool materials and transform them into superconductors. However, the situation changed dramatically in 1986. Bednorz and Mueller discovered a new type of superconductors, which is called cuprate superconductors.[5] Soon after their discovery, another cuprate superconductor which keeps superconductivity up to -180℃ was discovered by Chu.[6] The temperature -180℃ is still very low, but it can be relatively easy to achieve the temperature because liquid nitrogen which is cheap and common cryogen is enough. Thanks to the advantage, many applications of superconductors including superconducting power transmission changed to feasible.

The benefits of lossless power transmission using superconductor are not only to eliminate transmission loss by replacing the existing power grid but also to enable bold ideas that have been thought unrealistic due to transmission loss. Constructing a global power grid and globally averaging power consumption which depends largely on the time of day is one of such bold ideas. Generally, power demand is larger in the daytime and smaller in the nighttime, and power stations are constructed to be able to meet peak

demand. At present, to meet peak demand locally is required, hence there are a lot of extra power generation facilities when we consider globally. If power transmission between regions with different time zone becomes possible, these extra power generation facilities become unnecessary, which has a great economic and environmental benefit.
Another idea is to install huge solar power plants in a desert with many sunny days, such as the Sahara, and transmit generated power to large power consumption areas such as Europe by a distance transition. Thanks to lossless transmittance, the distance between power production areas and power consumption areas becomes less important, therefore it becomes possible to generate power that maximizes the potential of the land.

At the moment, superconducting power transmission technology is not widely used because of several problems. One of the main problems is cooling cost. Even when we use cuprate superconductors, which keep superconductivity up to relatively high temperature as mentioned above, superconductivity disappears without cooling. To overcome this problem, more efficient cooling technology has been studied, [7,8] and superconductors which keep superconductivity up to higher temperature have been investigated. [9,10] Another problem is that superconductivity disappears when the current passing through the superconductor reaches a certain value. Recent research reveals that this current value depends on the method of fabricating superconductors and develops a new fabrication technique.[11]
Although there are several problems, superconducting power transmission technology has reached the application test.[12] It is difficult to say exactly how many years later, but the day will come when superconducting power transmission will be widely used and will help solve energy problems, for example, as mentioned above.

References

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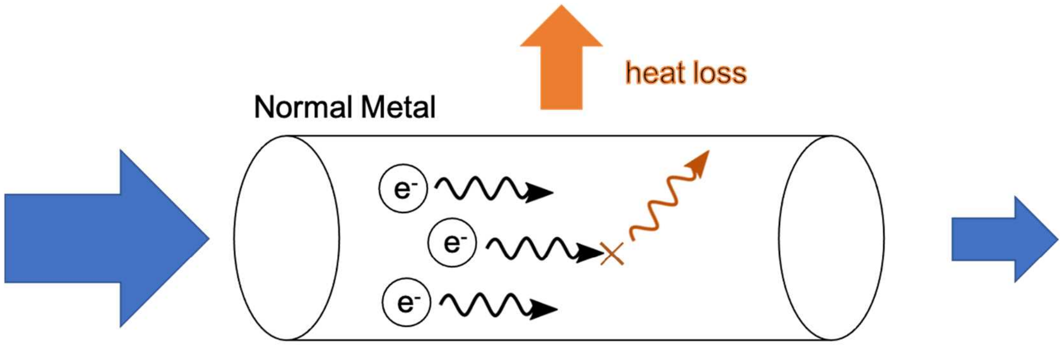
heat loss
Normal Metal
e-
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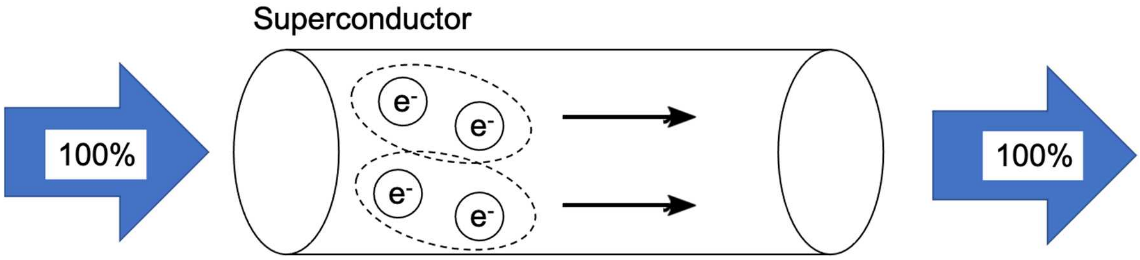
Superconductor
100%
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