Cold Power

Paul Michael Grant
W2AGZ Technologies
w2agz@w2agz.com
www.w2agz.com

Cold Power? What's that? Well, when I was a boy growing up in the Hudson Valley of New York during World War II, it meant having an electric refrigerator in your home instead of the far more common "ice box," [1]. Working class families, like mine, were not able to afford this modern marvel. We had one simply because my mother worked as a stenographer for the local electric utility company, and its employees were given the appliance to encourage more electricity use by the neighbors. Most families on the block had ice delivered daily by horse drawn carts with their inevitable spoilage of the streets (It was wartime, and gasoline was strictly rationed).

Later on, during my post-high school teenage days as a bench technician at IBM in the early 50s, Cold Power was having liquid helium on hand to explore the properties of emerging superconducting storage elements, such as the Crowe Cell [2]. Upon returning to IBM full time after obtaining my undergraduate and graduate degrees, I was assigned to its west coast research laboratory (today known as the Almaden Research Center). In the earlier 70s, we obtained one of the very first commercially available dilution refrigerators to help explore the milli-kelvin properties of the then newly discovered family of organic conductors, and thus stay a step ahead of our competition at Bell Laboratories. Now that was real "Cold Power!" We soon had on hand the necessary cryogenic infrastructure to explore the superconducting properties of a wide variety of exotic compounds including the 1986 discovery of high temperature superconductivity in copper oxides by our sister laboratory in Zurich [3].

But wait, Dr. Grant. Doesn't "Cold Power" also mean the lossless transport of electricity and its use in superconducting magnets employed today in large hadron colliders such as Fermilab and CERN? And what about the application to transmission cables, rotating machinery, transformers, fault current limiters, storage and the electricity enterprise in general, successfully demonstrated over the past five decades using both low and high temperature superconductors [4]? Yet, despite this success, significant deployment of superconductivity technology in the power delivery sector remains for the future [5]. In his letter to the April, 2015 issue of Cold Facts [6], Ralph Scurlock of Kyros Associates ponders, "What has happened to the Superconducting Dream?... The expected expansion of superconductivity into the electric power industry has fallen by the wayside…. The experience being developed *[Here Scurlock is referring to superconducting technology deployed at hadron collider facilities]* should be enabling the electric power industries to make enormous advances in large energy storage systems, cryogenic power cables, fault current limiters, etc. However, my dream of 1992 is still a dream."

I thoroughly understand and sympathize with Scurlock's frustration. During my 12-year career with the Electric Power Research Institute following retirement from IBM in 1993, I became quite familiar with the history and issues underlying power applications of superconductivity in the utility industry, especially in the United States. I summarized these in my 2011 Summer Cold Facts piece [6], "Upbraiding the Utilities," which was widely distributed among various US investor owned utilities. The "short story" is that there is currently "no compelling need" for widespread insertion of superconducting power devices in the US grid. Consider the following "extreme" example. In California, we have the Pacific Intertie [7], an 850 mile, 3.1 GW, +/- 500kV HVDC overhead link between hydroelectric resources in the Columbia River basin to the load center of the Los Angeles megapolis. It was begun in 1961, and over the years has undergone several incremental upgrades. Its performance record is excellent. It is estimated that the base ohmic loss on the Intertie is around 8%. Now, that's a big "absolute" number, but in essence "incremental" compared to total electricity production and consumption in the western United States. Would it be justified to tear down this well performing infrastructure to save this incremental energy loss, even if its superconducting replacement cost were to be zero? In actuality, the major losses on the Intertie are incurred by the converter/inverter stations at origin and arrival, which some estimates place as high as 25% (more about this to follow). Are there any new opportunities for significant insertion of superconducting cables in the US energy enterprise? Possibly. For example, the “dual use” of emerging natural gas pipeline rights-of-way to transport electricity generated at methane wellhead fields along with chemical energy. This scenario was briefly addressed in my 2014 October Cold Facts article [8], and more thoroughly online on the Smart Grid News website [9].

Another possible use of superconducting cables would be to link urban substations to promote load sharing and fault protection amongst such substations (known as the “Hydra” concept), given the rise of intermittent renewables, along with security and reliability concerns over storm damage and terrorist attracts. How practical and extensive such infrastructure might be is currently under study by a DHS/EPRI team of superconductivity and substation experts [Full disclosure: I’m a team member].

Are there other opportunities to deploy Cold Power on the US electricity scene other than superconductivity? Note I mentioned the significant power losses sustained in ac/dc/ac conversion. There is emerging, especially on the West Coast, a number of “micro-, smart-, resilient-“ grids (you choose the appropriate “buzz-adjective”), due to the rapidly growing use of residential and industrial solar PV generation. These micro-grids will likely…actually certainly… require a number of local inversion/conversion/storage stations, based on a combination of solid state device and chemical storage technologies. Cryogenic cooling, in the temperature range 100-200 K, could enable far more efficient frequency conversion in the former, which has been demonstrated for MOSFET power devices. Such advantage would be especially true for thyristor-based silicon controlled rectifiers, but would require careful design of junction doping materials and profiles to circumvent minority/majority carrier freezeout that would accompany such if conventional room temperature devices were to be simply cooled down. Studies of cryo-cooled power electronic devices were undertaken by EPRI in the late 90s, but not completed due to reduction of funds available for R&D arising from deregulation. Perhaps it is now time to revisit application of Cold Power to power electronics.

In the meantime, until we can eventually engender Cold Power for the People, let’s all try to keep our cool…aka patience, persistence and perseverance.

References

1. An early refrigerator design patented in 1927 by then two still relatively unknown physicists, at least to the general public. It did not employ a pump/compressor, but rather temperature differentiation which in principle could be electrically driven. http://w2agz.com/Library/Variosos/Einstein-Szilard%20Patent%20US1781541.pdf
2. J. W. Crowe, “Trapped Flux Superconducting Memory,” IBM Journal, October 1957, p.295. http://w2agz.com/Library/Variosos/Crowe%20Cell/Jim%20Crowe,%20%281957%29%20ibmrd0104B.pdf
3. B-M discovery J.G. Bednorz and K.A. Mueller, “Possible High Tc Superconductivity in the Ba-La-Cu-O System,” Z. Phys. B. – Condensed Matter 64, 189 (1986). http://w2agz.com/Library/HTSC%20History/%281986%29%20Bednorz%20-%20Mueller,%20Z%20Phys%20B%20%28CM%29%2064,%20189.pdf
4. Paul Michael Grant, “Superconductivity and Electric Power: Promises, Promises…Past, Present and Future,” IEEE Trans. Appl. Supercon 7, 112 (1997) http://w2agz.com/Publications/Science%20&%20Technology/EPRI/01%20%281997%29%20Superconductivity%20and%20Electric%20Power%20-%20Promises,%20Promises%20---%20Past,%20Present%20and%20Future.pdf
5. Paul Michael Grant, “Superconducting Transmission Lines for the Transmission of Large Amounts of Electrical Power Over Great Distances: Garwin-Matisoo Revisited Forty Years Later,” IEEE Trans. Appl. Supercon. 17(2), 1641 (2007). http://w2agz.com/Publications/Science%20&%20Technology/W2AGZ/04%20%282007%29%20Grant,%2

0Garwin-Matisoo%20Revisited,%20IEEE%20Trans%20Appl%20Supercon%2017%282%29%201641%20%282007%29.pdf

6. Paul Michael Grant, “Upbraiding the utilities,” Cold Facts 27(3), 4 (2011). http://w2agz.com/Publications/Opinion%20&%20Commentary/W2AGZ/Cold%20Facts/2011/Summer%202011%20Upbraiding.pdf
7. https://en.wikipedia.org/wiki/Pacific_DC_Intertie
8. Paul Michael Grant, “Superconductivity: Will It Be Coming in from the Cold?,” Cold Facts 30(5), 36 (2014). http://w2agz.com/Publications/Opinion%20&%20Commentary/W2AGZ/Cold%20Facts/2014/Coming%20in%20from%20the%20Cold.pdf
9. Paul Michael Grant, “Smart grid transmission: How “twins” could double our benefits,” 9 April 2013. http://w2agz.com/Publications/Opinion%20&%20Commentary/W2AGZ/Smart%20Grid%20News/Fraternal%20Twins.pdf