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Speaker's name and affiliation
Prof. Hirofumi Akagi, Tokyo Institute of Technology,
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Tutorial title:
"Bidirectional Isolated Dual-Active-Bridge (DAB) Converters: Fundamentals and Applications."

Abstract:
This tutorial will begin with a historical review of bidirectional isolated dual-active-bridge (DAB) converters, focusing on circuit and control, with reference to some seminal research papers. The technical term "dual-active-bridge" is derived from the circuit topology, whereas the term "bidirectional isolated" is derived from the functionality. Due to its simpler naming, the DAB converter would be preferable to the bidirectional isolated dc-dc converter. Circuit configurations classify it as either single-phase or three-phase and either resonant or non-resonant. In addition, applications allow it to be divided into the following two groups: One group is that the voltage ratio of the dc input to output terminals is always equal to the turns ratio of the transformer installed to achieve galvanic isolation between the dc input and output terminals. This situation occurs when the DAB converter is integrated into a converter cell of a multilevel converter. The other group is that the voltage ratio is not equal to the transformer's turns ratio with a difference of about 20%. This situation occurs when the DAB converter is connected directly to a battery pack or system. It is known that the former has a higher conversion efficiency than the latter.

Haneda and Akagi designed, built, and tested the 850-Vdc, 100-kW, 16-kHz DAB converter consisting mainly of two 1.2-kV 400-A SiC-MOSFET/SBD quad (4-in-1) modules and a unity-turns-ratio transformer using a nanocrystalline soft-magnetic material. The 100-kW DAB converter, which underwent experimental verification, demonstrated the attainment of high levels of efficiency from the dc input to output terminals under three distinct yet meaningful operating conditions. The efficiency levels attained were 99.2% at 100 kW, 99.5% (peak efficiency) at 34 kW, and 99.2% at 10 kW. These results were achieved while maintaining "zero-voltage switching (ZVS)" in all the operating regions. In light of the comprehensive power-loss analysis conducted on the basis of the aforementioned experimental findings, Akagi postulates that the DAB converter will attain an exemplary high level of efficiency, reaching 99.6% or above at the rated power by 2035. This is a consequence of the ongoing advancement in the performance of SiC-MOSFET modules and magnetic devices. Such an elevated level of efficiency would permit the elimination of cooling fans, which are regarded as lifespan components, from heat sinks.

This tutorial will conclude with an examination of some prospective applications of DAB converters in the near future, including the "solid-state transformer (SST)."

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Tutorial title:
"The Neutral-Point-Clamped Inverter and Instantaneous-Power Theory: How They Emerged in the Early 1980's."

Abstract:

This tutorial will disclose unknown success stories of the three-phase three-level neutral-point-clamped (NPC) inverter and the three-phase instantaneous-power theory or *p-q* theory. Both inverter and theory emerged from the Technological University of Nagaoka (currently the Nagaoka University of Technology), Nagaoka, Japan, in the early 1980's. Behind that, there were technical advances in power bipolar junction transistors (BJTs) all through the 1970's.

Nabae, Takahashi, and Akagi designed, built, and tested an adjustable-speed motor drive that combined the three-phase NPC inverter using 12 BJTs, 12 free-wheeling diodes, and six clamping diodes with a three-phase induction motor. They presented the world's-first short paper with experimental results at a Japanese domestic conference in March 1980. Then, they presented the full paper at the IEEE Industry Applications Society Annual Meeting in October 1980, and had the paper published in the IEEE Transactions on Industry Applications in September 1981. At the same time, Baker applied for a patent on the three-phase NPC inverter circuit in August 1979, and it was registered and published in May 1981. However, he did not include any experimental verification in his patent.

Akagi succeeded in defining and formulating a new pair of instantaneous real and imaginary powers, p and q, for three-phase circuits in November 1981. Three months later, he gave a strict mathematical proof to a clear explanation of the physical meanings of p and q. This definition and formulation made it applicable to any waveform without any restriction because both used only the information of the present voltages and currents. Thus, it was named the "*p-q* theory" later. Akagi, Kanazawa, and Nabae presented the world's-first paper on the theory at an international conference in March 1983. The IEEE Transactions paper following the conference paper was published in May 1984, including experimental verification.

The emergence stories of the NPC inverter and the *p-q* theory would remind us of Newton's famous quote: "Necessity is the mother of invention," and Galilei's famous quote: "Doubt is the father of invention," respectively.