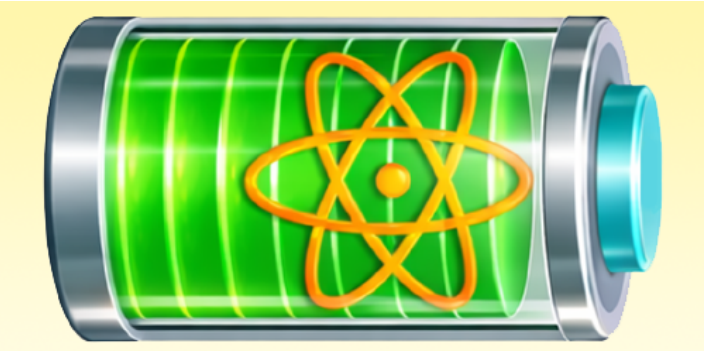
How Reliable Are Quantum Batteries?

Increasing the charging rate of a quantum battery leads to unavoidable fluctuations in the total energy stored.

By **Marric Stephens**

A quantum battery exploits quantum correlations between its component cells to achieve charging and discharging rates that are unattainable for classical devices (see **Viewpoint: Sizing Up the Potential of Quantum Batteries**). Now Brij Mohan at the University of Oulu in Finland and colleagues have quantified the trade-off between that advantage and a quantum battery's ability to deliver steady, reliable energy [**1**]. The researchers also identified a battery architecture that optimizes both performance and reliability.

Central to the team's analysis is the relationship between power and work. Like momentum and position, in quantum physics these quantities are noncommuting, which means that their fluctuations cannot be simultaneously reduced to arbitrarily small values. Consequently, reducing the battery's power fluctuations increases the fluctuation in the total work delivered, and vice versa. The inherent quantum dynamical fluctuations that affect each quantity independently also come into play.



Credit: B. Mohan *et al.* [**1**]

Mohan and colleagues considered these uncertainties and set theoretical lower limits on the power or work fluctuations for a given value of the other quantity. Then they investigated how changing the "quantumness" of the battery affects these limits. A battery in which each cell charges or discharges independently is said to be uncorrelated. As more cells are added to such a battery, the product of the power and work fluctuations drops quadratically—that is, as the square of the number of cells—and assumes a small value. But its power increases only linearly. For a battery of fully correlated cells, power scales quadratically as cells are added, but the product of the power and work fluctuations is maximal. A battery with range-limited interactions, in which more distant cells are uncorrelated, hits the sweet spot between power scaling and reliability.

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REFERENCES

1. B. Mohan *et al.*, "Fundamental limitations on the reliabilities of power and work in quantum batteries," **PRX Quantum 7, 033057 (2026).**