

# Limitations of Fault-Tolerant Quantum Linear System Solvers for Quantum Power Flow

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Quantum computers hold promise for solving problems intractable for classical computers, especially those with high time or space complexity. Practical quantum advantage can be said to exist for such problems when the end-to-end time for solving a problem using a classical algorithm exceeds that required by a quantum algorithm. Reducing the power flow (PF) problem into a linear system of equations allows for the formulation of quantum PF (QPF) algorithms, which are based on solving methods for quantum linear systems such as the Harrow-Hassidim-Lloyd (HHL) algorithm. Speedup from using QPF algorithms is often claimed to be exponential when compared to classical PF solved by state-of-the-art algorithms. We investigate the potential for practical quantum advantage in solving QPF compared to classical methods on gate-based quantum computers. Notably, this paper does not present a new QPF solving algorithm but scrutinizes the end-to-end complexity of the QPF approach, providing a nuanced evaluation of the purported quantum speedup in this problem. Our analysis establishes a best-case bound for the HHL-based quantum power flow complexity, conclusively demonstrating that the HHL-based method has higher runtime complexity compared to the classical algorithm for solving the direct current power flow (DCPF) and fast decoupled load flow (FDLF) problem. Notably, our analysis and conclusions can be extended to any quantum linear system solver with rigorous performance guarantees, based on the known complexity lower bounds for this problem. Additionally, we establish that for potential practical quantum advantage (PQA) to exist it is necessary to consider DCPF-type problems with a very narrow range of condition number values and readout requirements.