Quantum Quants and TNO: Electrical Grid Optimization Powered by Quantum Computing

CASE STORY

Optimizing the Decentralized Power Grid

In the not-so-distant past, power grids had a relatively straightforward configuration, with most households and businesses drawing energy from centralized power plants. By comparison, today's grids are far more elaborate and decentralized, with the ongoing effects of climate change and geopolitical conflict exerting profound but unpredictable effects on both the cost of and demand for energy.

Conventional approaches to grid management are ill-suited for grappling with such complexity, but optimization strategies that leverage D-Wave's quantum computing platforms are up to the task. A recent study from Netherlands-based researchers at Quantum Quants in Rotterdam and the Netherlands Organization for Applied Scientific Research (TNO) in The Hague demonstrates that a combination of quantum and classical computing methods offers a robust and scalable solution for the efficient design and management of 21st-century energy infrastructure.

Complexities of the Modern Power Grid

"In 2023, the share of global electricity generated by renewable sources was just below 50%, with solar and wind leading the charge," said Giuseppe Colucci, from Quantum Quants. External factors can also create challenges, such as the 2022 spike in natural gas prices at the start of the

When comparing classical solvers to D-Wave's quantum-hybrid solvers, the D-Wave solvers—and the CQM solver in particular— found far better solutions for the more challenging grid scenarios. Indeed, researchers noted that the results from these solvers are closer to the best possible solutions compared to the results of the classical solvers.

Russia-Ukraine war. This was followed by an exceptionally mild European winter that led to a considerable drop in electricity demand and an unexpected energy surplus.

To accommodate these complexities and control energy costs, contemporary grids must be resilient and capable of rapid and efficient redistribution of unused surplus power to zones where the demand remains relatively high. This challenge spurred Quantum Quants to collaborate with researchers from TNO on the development and benchmarking of a quantum computing-powered solution.

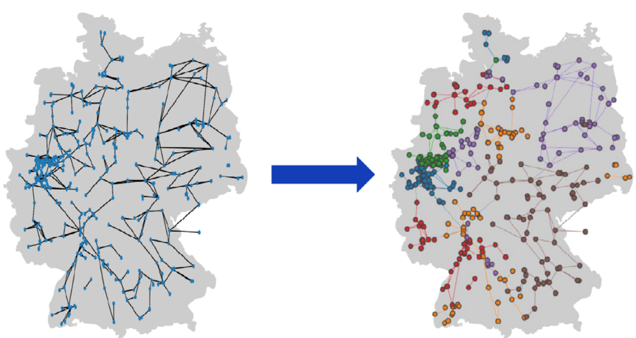
Quantum Annealing: Ideal for Optimization

Quantum annealing is an excellent fit for this sort of optimization problem, allowing the rapid algorithmic identification of efficient solutions to complex problems that would be impossible to resolve with classical computing. In this particular case, the Quantum Quants and TNO team focused on optimizing the management of surplus energy in decentralized power grids of increasing size and complexity.

Their process entailed converting the grid to a graph structure, in which sites of energy production are depicted as "nodes" connected by "edges" that represent power transmission lines. A network in which all nodes are interconnected would prevent wasted surplus energy, but would also be too expensive and complex to engineer and maintain. Instead, the solver algorithm needs to find clever ways to partition the network into smaller subnetworks of interconnected nodes within which surplus power can be efficiently redistributed. “We have the lowest cost when all the partitions have roughly equal sizes, but we are [also] doing this on an existing network,” said a TNO researcher. This means the solver should use existing transmission line “edges” in the graph as much as possible, and minimize creation of new ones.

In an initial test of their approach, the team examined how well a pure quantum annealing-based approach, powered by the D-Wave Advantage™ system, could perform with relatively small, simulated power grids for which the optimal solution was already known. The quantum solver consistently produced the correct solution, even with grids incorporating more than 100 nodes. However, this

National Power Grid for Germany



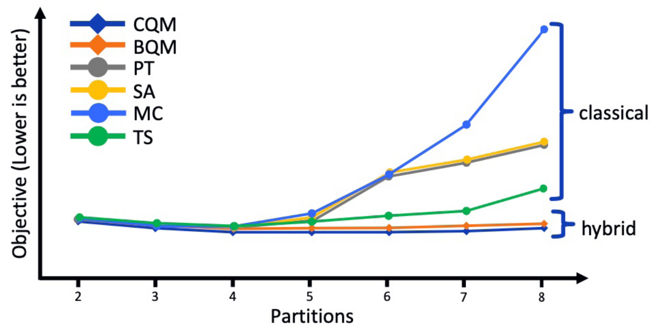
is still much simpler than the kinds of grids that must be optimized in the real world.

For example, graphs of the actual national power grid for Germany include over 400 nodes connected by more than 500 edges. To tackle these tougher problems, researchers turned to the D-Wave hybrid solvers that couple the strengths of classical and quantum computing. They ran two different hybrid solvers, the constrained quadratic model (CQM) and binary quadratic model (BQM) solvers. The resulting solutions were then compared against those devised by four different classical solvers.

The differences were stark. Although all solvers performed equivalently for solutions requiring just two or three partitions, the two hybrid solvers—and the CQM solver in particular—found far better solutions when confronted with challenging grid scenarios requiring six or more partitions. Using larger numbers of partitions is more realistic, given the microgrid structure of large networks.

The team noted that the results from these solvers are closer to the best possible solutions compared to the results of the classical solvers.

Results: quantum vs classical



(Lower is better)

• Fair comparison: all methods are run on the cloud with a time limit of 10 seconds.

• The “winner”: The BQM and CQM solvers outperform the classical methods, with the CQM solver providing the lowest objective value for all numbers of partitions.

• Stability: classical methods show a drop in the quality of the solution for a large number of partitions.

The Quantum Quants ad TNO researchers were pleased with the outcome of the study: “This is one of the first actual implementations and one of the first business applications in the energy sector using quantum annealing.” And as the complexities of the energy market continue to grow, further innovations in the quantum computing space could prove critical for helping governments and energy providers to arrive at smart solutions for efficient power distribution.

For more information, see the paper at [https://ieeexplore.ieee.org/abstract/document/10247202.](https://ieeexplore.ieee.org/abstract/document/10247202)