Green Optimization on a Quantum Annealer

A cost-efficient optimization of energy networks to reduce carbon emissions

THE SPIN DOCTORS, CDL Quantum 2021, Hackathon

Climate change is the biggest challenge of our era, and a vital issue for **electrical energy distributors**.

Today, energy grid distribution focuses on optimizing for lowest operating costs, leaving consumers to offset their CO2 emission with different methods, like carbon trading credits.

Green Optimization is the solution to this problem.

By co-optimizing for reduced CO_2 emissions and operational costs we help Transmission System Operators go green and save money at the same time.

All of this, as never before, thanks to **Quantum Computing**.

OUR VISION

We move the world closer towards a net-zero emissions future, by addressing the release of carbon at the source.

We don’t simply convince Transmission System Operators that is the right thing to do for our planet: we help them understand how to **optimize revenues** by **reducing their need to offset CO2 emission**, distributing power more cleanly and efficiently.

OPTIMIZATION TODAY

Optimization models have been widely used in the electric power industry to solve the **unit commitment** problem (UC), the process of scheduling and dispatching electric power generation resources.

UC is considered an NP-hard problem, and an active field of research *[a1, a2]*. The inclusion of renewable energies into the system poses an additional challenge.

Deterministic *[a3]*, meta-heuristic *[a4]* and combinatorial approaches, from deep learning *[a5]* and simulated annealing *[a6]* have been applied with different degrees of success.

Our solution: The Green UC optimizer

Our solution provides a prototype to solve UC in a **Green Optimization** framework by using **Quantum Annealing**.

We call this problem the **Green Unit Commitment problem** (GUC).

GUC can be formulated as a (multi-objective) QUBO problem, amenable to be solved on a quantum computer, with a cost function expressing the **trade-off** between:

- **Operational** costs: usage, maintenance, fuel and on-off related costs
- **Carbon emission** costs: proxied by price of Renewable Energy Certificates or carbon taxes

We define the variables $s_{i\alpha}$ related to the activity of a given energy source at a given time in the schedule:

$$H_L = \sum_{i,\alpha} (c_o^\alpha + c_e^\alpha) \cdot s_{i\alpha} \qquad H_Q = \sum_{i,\alpha,\beta} (c_{off}^\alpha + c_{on}^\beta) \cdot s_{i,\alpha} s_{i+1,\beta}$$

under the constraint that the generated power satisfies the load demand:

$$\sum_{\alpha} p_\alpha \cdot s_{i\alpha} - d_i \geq 0$$

Our solution: Green UC Optimizer

We optimize the GUC on the **D-Wave Leap Hybrid Solver.**

Alternative quantum and classical implementations have been performed to test the performance of the solver.

These include:

- **Simulated Annealing (D-Wave)**
- **Quantum Annealing (D-Wave)** and
- **QAOA (implementation in Rigetti SDK and IBM Qiskit)**.

Extension to realistic scenarios

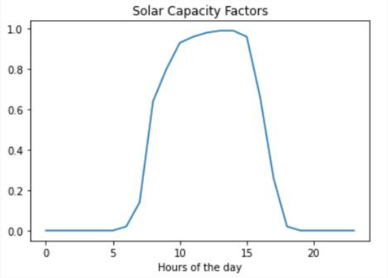
For the GUC problem we used:

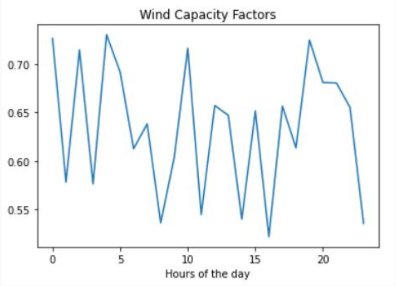
- Real energy load demand data
- Real plant operating costs and synthetic cost usage for several different energy sources (gas, nuclear, solar, wind, hydro, coal) based on real data (https://www.eia.gov/)
- Proxied Carbon emission costs based on US Real Renewable Energy credits (REC) prices.

Further, we extended the analysis to a larger network by including:

- Additional sources (coal, nuclear)
- Stochastic nature models for of wind and variability of solar power

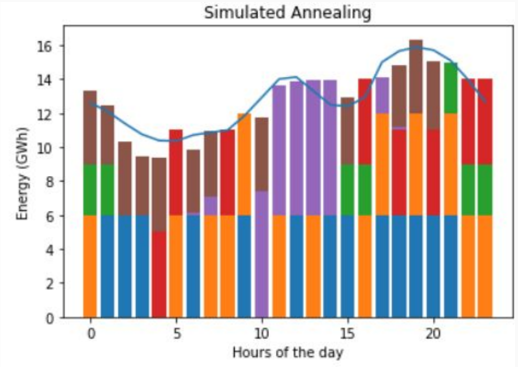
The prototype allows for extensions to use arbitrary schedule size and number of energy sources.

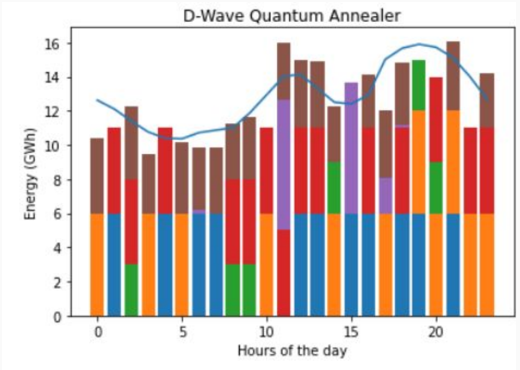


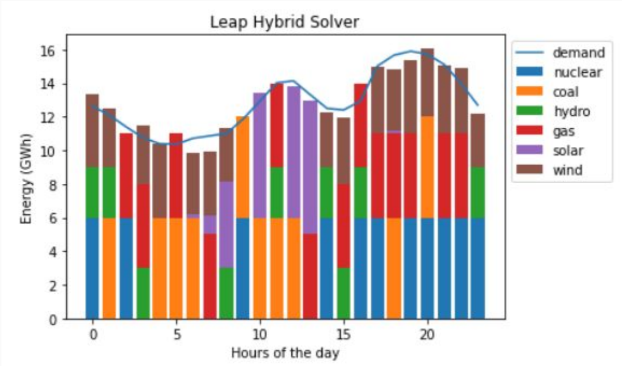


D-Wave Classical, Quantum and Hybrid annealers

1 day hourly resolution







POTENTIAL CUSTOMERS

Transmission System Operators, entities entrusted with transporting energy in the form of natural gas or electrical power on a national or regional level.

- Terna, Italy, € 2513.5 million of revenues in 2020 [1]
- NationalGrid, UK, £ 2780 million of revenues in 2020 [2]
- IESO, Canada, $ 195.2 million of revenues in 2020 [3]
- AESO, Canada, $ 2326.8 million of revenues in 2020 [4]

COMPETITORS

AXpo - Has already implemented new strategies for transition to renewable sources. However, still has no plan to use quantum computing applications to develop new strategies for renewable transitions.

ABB - Offers consulting and solutions for the energy sector, their main framework is based on classical data and still has no use of quantum computing optimization.

IBM - The IBM Energy&Utilities department has a plethora of applications and real use cases for the management of energy resources using AI and their Cloud environment. However, they are still lacking green and quantum optimization for this sector.

Optimize revenues and reduce your carbon footprint as no-one else is able to.

Unleash Quantum Computers for a green future.

GO GREEN, GO QUANTUM.

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REFERENCES

[a1] Quantum-Enhanced Grid of the Future: A Primer

[a2] Unit commitment in electrical power system-a literature review

[a3] A deterministic method for the unit commitment problem in power systems

[a4] Solution of the unit commitment problem by the method of unit periods

[a5] A Novel Short-Term Load Forecasting Method by Combining the Deep Learning With Singular Spectrum Analysis

[a6] Quantum computing for energy systems optimization: Challenges and opportunities

[b1] Terna 2020 Integrated Annual Report

[b2] National Grid 2020/21 Full Year Results Statement

[b3] IESO Financial Report 2020

[b4] AESO 2020 Corporate Governance and Financial Results