Electric industry use-case supported by PNNL for the Quantum Computing Hackathon: Optimal resource scheduling for daily operations

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September 2023

1 Introduction

The electric power industry is amidst a transformation with new technology, digitization, and increased connectivity. Rooftop solar panels, electric vehicles, and microgrids are providing the end use customers with new means of generating electricity locally, while renewable energy technologies (such as wind, solar, etc.) are spearheading the decarbornization efforts. Regulatory policies around the world favoring electrification and renewable energy sources are expected to drive the push to green energy with targets (100% carbon-free electricity by 2035 for U.S.). At the same time, we are witnessing an increase in the growth of extreme weather events causing severe damage to the electric grid. The big Texas freeze of 2021, rampaging wild fires in the U.S. West Coast, and hurricane Maria, Ian, and others, are examples of devastating events that have caused billions of dollars of damage to the grid.

An important problem for electric planners and operators is the scheduling of resources to meet the ever fluctuating demand. This problem is called a "unit commitment" problem which in its entirety a multi-period mixed-integer linear optimization with the objective of finding the least cost resource dispatch meeting the needed electricity demand and meet the grid and resource constraints. We present the unit commitment problem in its bare minimum form here to motivate the use-case. The full problem in its entirety is discussed in [2]. An approach for solving the unit commitment problem using quantum computing is described in [1].

A use case with similar formulation is for the aggregators to schedule the distributed energy resources (DERs) in distribution systems. Aggregators are entities that can manage the distributed energy resources (e.g., battery storage systems, solar panel/farms, wind farms, EV charging stations) and loads (e.g., HVAC, heat pump, electric heater, smart appliances), via communication networks. Aggregators can remotely monitor and control each DER device to increase or decrease the power consumption according to various economic signals and engineering criteria and constraints. Aggregators play a critical role in the operation of modern power systems, such as to promote renewable energy integration and electrification, provide grid services, participate in wholesale markets. There can be many aggregators managing different types of DERs, and they work with utiliy system operators to make sure the electric power system is operating efficiently. A typical use case is to manage the electric vehicle (EV) charging at a charging station, which can be considered as an aggregator. The charging station can be open for public or owned by a company (e.g, utility's vehicle fleet, USPS, AMAZON). Assume the charging station aggregator wants to maintain the total charging power D_t during each time period t, while minimizing the total charging cost, which is calculated based on the energy price c_i and the total power consumption of a total of N vehicles during each time period: $\sum_{t=1}^{T}\sum_{i=1}^{N} c_i x_{i,t}$. The charging power of each vehicle $x_{i,t}$ is adjustable within a range $[x_i^-, x_i^+]$. Assume the EVs may arrive at the charging station at different times and have different charging windows, we use $u_{i,t}$ to indicate if an EV i is connected to the charger for charging during time period t. To simplify the problem, we assume EVs can be continuously charged throughout the entire planned time duration (0 to T) without reaching the maximum state of charge (SOC).

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2 Formulation

The resource scheduling or unit commitment problem is described in (1–4). The goal of the unit commitment problem is to minimize the total cost of power produced over a given horizon (typically 24 hours) while meeting the total electricity demand for each hour (2, unit capacity constraints (3, and the ramping constraints (4).

$$\min. \sum_{t=1}^{T}\sum_{i=1}^{N} c_i x_{i,t} \tag{1}$$

s.t.

$$\sum_{i}^{N} x_{i,t} = D_t, \forall t \in T \tag{2}$$

$$u_{i,t}x_i^- \leq x_{i,t} \leq u_{i,t}x_i^+, \forall t \in T \tag{3}$$

$$x_{i,t} - x_{i,t-1} \leq r_i, \forall t \in T \tag{4}$$

Here, $x_{i,t}$ is the power produced by generation resource i at time t,
N is the total number of generation resources available,
T is the time horizon for scheduling,
D_t is the total electricity demand at time t,
$u_{i,t} \in 0, 1$ is the commitment (on/off) status of unit i at time t,
x_i^- and x_i^+ is the minimum and maximum power production from resource i,
r_i is the limit for power production deviation for unit i going from time $t-1$ to time t,
c_i is the marginal cost for unit i

References

[1] Halffman, P., Holzer, P., Plociennik, K., and Trebing, M. A quantum computing approach for the unit commitment problem. *arXiv preprint arXiv:2212.06480* (2022).

[2] Montero, L., Bello, A., and Reneses, J. A review on the unit commitment problem: Approaches, techniques, and resolution methods. *Energies 15*, 4 (2022).