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Asynchronous Decentralized Framework for Unit Commitment in Power Systems

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Abstract

Optimization of power networks is a rich research area that focuses mainly on efficiently generating and distributing the right amount of power to meet demand requirements across various geographically dispersed regions. The Unit Commitment (UC) problem is one of the critical problems in power network research that involves determining the amount of power that must be produced by each generator in the power network subject to numerous operational constraints. Growth of these networks coupled with increased interconnectivity and cybersecurity measures have created a need for applying decentralized optimization paradigms. In this paper, we develop a novel asynchronous decentralized optimization framework to solve the UC problem. We demonstrate that our asynchronous approach outperforms conventional synchronous approaches, thereby promising greater gains in computational efficiency.

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Keywords: decentralized optimization, unit commitment, asynchronous methods

1 Introduction

Large scale power networks form the backbone of the global energy infrastructure. A surge in global power consumption now demands better energy distribution schemes as well as increased efficiency in the management of power network resources and assets. Among the most critical assets of any power network infrastructure are the generators which produce electricity and the buses which demand power. The buses and generators form a part of the power network topology where the generators collectively aim to meet the total demand imposed by all the buses while also adhering to network-wide requirements on the flow of electricity. Power network optimization problems aim at better utilization of the generators and form a significant part of power systems research. The Unit Commitment (UC) problem [1] is one of the key optimization problems that has received considerable attention over the past few decades. The goal of the

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UC problem is to determine how much power each generator has to produce given the cost of production and the power demand to be met.

The UC problem is a critical component for daily production planning for power utility companies. Utility companies that command power networks typically solve the UC problem many times throughout the entire day to determine the production levels of different generators on an hourly basis. The power network is subject to demand uncertainties that require constant monitoring and adjustments to power generation. There may also be sudden and unpredictable outages caused by natural or man-made phenomena that may disrupt the highly sensitive, hourly production schedule of the generators network-wide. An efficient algorithm for solving the UC problem therefore needs to be highly robust to sudden changes in operating conditions. The UC problem involves binary decision variables to decide which generators must be turned on or off at various time epochs across a fixed planning horizon. The resulting optimization model of the UC problem therefore becomes a Mixed Integer Programming (MIP) problem that falls under the category of non-convex optimization problems.

A large-scale power network is topologically divided into a number of regions which may represent different power utility companies or subsidiaries. Traditionally, a centralized model has been employed to conduct unit commitment on power networks. However, the centralized model has several drawbacks. First, centralized methods are unable to isolate potentially sensitive commercial operations data. Second, the performance of a centralized model for unit commitment deteriorates with increase in network size leading to poor scalability thereby making it unsuitable for large-scale power networks. Third, an attack on a single node can compromise the entire power network.

Decentralized optimization methods have lately emerged as a means to tackle the different operational issues presented above. Owing to a loose coupling between regions, the global UC optimization problem can be decomposed into smaller subproblems, each corresponding to a particular region. By iteratively solving each region's subproblem locally and exchanging information with neighboring subproblems, we can completely decentralize the solution to the global UC problem. Since each subproblem is locally held by the region itself, decentralized methods retain privacy of commercial data pertaining to each region. Further, decentralized methods enable solving for the global optimum only on the basis of local infrastructural data and relevant operational data points of neighboring regions thereby improving scalability.

Existing approaches to decentralized unit commitment problems [2] adopt a synchronous approach wherein each iteration of the local subproblem and the subsequent information exchange is performed in tandem by all regions. Owing to a tight coupling between computation and communication, the information obtained from neighboring regions in the synchronous approach is always pertaining to the current iteration. Such synchronous models do not account for geographically distant computational nodes wherein transfer of data between nodes comes with its own communication delay. At different nodes, different subproblems and computing architectures with varying computational capabilities will lead to heterogenous processing times. This variability in the computation time would be further compounded by time-varying loading on the computing resources due to on-line control of many connected assets in the region. Therefore, methods that rely on synchronization of computational nodes do not account for delays incurred in practice. Consequently, in large-scale distributed systems involving many interconnections, achieving perfect synchrony is extremely difficult [3]. Furthermore, synchronous computational methods may simply fail to converge in the face of even a slight degree of asynchrony [4]. Even with a hypothetical synchronous computation system, a slow computational node or communication link can significantly increase the computational time by under-utilizing the computing resources. This causes all the computational nodes to wait until the problematic