Chapter 107
Future Directions to the Application of Distributed Fog Computing in Smart Grid Systems

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ABSTRACT

The rapid growth of new technologies in power systems requires real-time monitoring and control of bidirectional data communication and electric power flow. Cloud computing has centralized architecture and is not scalable towards the emerging internet of things (IoT) landscape of the grid. Further, under large-scale integration of renewables, this framework could be bogged down by congestion, latency, and subsequently poor quality of service (QoS). This calls for a distributed architecture called fog computing, which imbibes both clouds as well as the end-devices to collect, process, and act upon the data locally at the edge for low latency applications prior to forwarding them to the cloud for more complex operations. Fog computing offers high performance and interoperability, better scalability and visibility, and greater availability in comparison to a grid relying only on the cloud. In this chapter, a prospective research roadmap, future challenges, and opportunities to apply fog computing on smart grid systems is presented.

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INTRODUCTION

Unlike conventional power systems, smart grid today is a healthy amalgamation of multiple interoperable, scalable, efficient, sustainable and secure technological domains contributing holistically towards the availability, reliability, and quality of the power generated, transmitted, and distributed to consumers. These technological domains extend beyond power systems themselves, manifesting as data management, cyber-physical security, human behaviors, mathematics, communication, and even wireless sensors. Such an interconnected smart grid can provide sustainable and reliable power delivery, ensuring availability and eco-friendly means of generating power. Integrating many renewables into the grid, at both transmission as well as distribution levels, is expected to yield an unstable grid owing to their intermittent nature. This necessitates the need for smoothing as well as optimizing the cost of operation, production, and distribution (Popeanga, 2012). Consumers have now metamorphosed into "prosumers", wherein they have gained the ability to both produce as well as consume power. With the integration of more intelligent sensors and devices on the field, largely distributed across the grid, Internet of Things (IoT) has gained prominence in this critical infrastructure as well. These devices churn data points constantly, racing to the central servers bolstered by strong and resilient communication infrastructure (Dastjerdi & Buyya, 2017). Consequently, the significance of computing in the smart grid domain must be investigated. For this purpose, three sub-domains within the smart grid will be explored in this chapter: information management, energy management, and security.

Significance of Computing in Information Management

Currently, the deluge of digital data is centrally ingested and cleansed into useful information blocks that can be processed. Many critical power system applications such as Demand Response (DR), load flow and Optimal Power Flow (OPF) analyses, fault and reliability analyses, quality assurance models, customer billing processes, direct load control, active/reactive power control and distribution planning, to name a few, depend on the veracity and validity of the information gathered from the field. This warrants the need for effective and powerful computing technologies for smart grid.

Significance of Computing in Energy Management

The existing power grid needs an optimal balance of electricity demand and supply between consumers and the utilities. The smart grid can address this requirement. Such features in a smart grid are realized by the integration of various Energy Management Systems (EMSs) such as Home Energy Management (HEM), Demand Side Management (DSM), and Building Energy Management Systems (BEMS) (Fang, Misra, Xue, & Yang, 2012). A smart grid allows various renewable energy sources (such as solar and the wind) to have the efficient management of supply and demand. In the emerging smart city and microgrid scenarios, EMS is one of the most important cornerstones. Naturally, for the efficient and continuous operation of such complex ecosystems within the grid, computation will play a crucial role. With the integration of secondary storage devices such as batteries and supercapacitors, optimal economic dispatch, peak load shaving, and other operations will be required at micro-grid level. Under such scenarios, effective distributed computing methods need to be added on top of the underlying power infrastructure.