Scalable Offline and Online Decision-Making for Next-Generation Autonomous Power Systems

Rui Cheng

**Abstract**: Traditional power systems always rely on the fossil-fuel based power, the power is determined and dispatched in the centralized decision-making process. However, recent years have seen the increasing proliferation of distributed energy resources (DERs), communication, computing, and information devices in power systems, becoming next-generation autonomous power systems. On the one hand, the high penetration of DERs can provide a variety of benefits to next-generation autonomous power systems. For example, DERs can respond rapidly to near-term generation or reliability-related requirements, further improving their ability to enhance power system reliability and reduce costs. On the other hand, DERs have led to significant uncertainty and intermittency in power system controls and operations, especially for power system economic dispatch and voltage regulation problems. It becomes increasingly urgent to explore how to utilize DERs to improve power system efficiency, reliability, and resilience while mitigating the negative impacts of DERs on power systems.

Traditional power system decision-making is the centrally-managed formulation and solution of system-wide optimizations. It always entails large amounts of computation time and information coming from customers, leading to customer privacy and scalability problems. Particularly, the capacity of each DER is always small, but the number of DERs in power systems is massive. Given such distribution characteristics of DERs, it might be impractical to apply traditional power system decision-making to autonomous power systems. To figure out this dilemma caused by DERs, it calls for new and innovative decision-making strategies to adapt to new characteristics of autonomous power systems:

(1) The capacity of DERs is usually small, but the number of DERs is very massive. In addition, DERs are distributed across power systems. Coordinating massive DERs at different network locations is a big scalability challenge.

(2) The uncertain and intermittent nature of DERs makes the operations of autonomous power systems more complicated, leading to different environmental change rates. Different environmental change rates might require different decision-making strategies. Offline decision-making strategies are suitable for slow environmental change rates since there is enough time for the algorithm convergence. In contrast, fast environmental change rates require online decision-making strategies to adjust the decision variables in real time.

(3) The increasing deployment of communication, computing, and information devices, along with increasing data, will bring many opportunities and changes to autonomous power system decision-making. It has attracted increasing attention worldwide utilizing these devices and data to make better decisions for autonomous power systems.

To this end, this work aims to propose scalable offline and online decision-making for next-generation power systems, utilizing DERs to enhance power system efficiency, reliability, and resilience. In particular, we focus on developing and designing offline and online decision-making to resolve a series of power system problems, including energy management, voltage regulation, and power flow problems.