

Safe Deep Reinforcement Learning for Resilient Self-Proactive Distribution Grids Against Wildfires

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With the growing risks and frequency of wildfires, power distribution systems (PDS) face significant challenges in maintaining reliability and security. Existing literature primarily focuses on post-event service restoration using stochastic optimization methods. Nevertheless, such approaches fall short in managing the dynamic and uncertain nature of wildfires, particularly when it comes to taking proactive measures to mitigate power outages. To address this problem, this paper introduces a wildfire smart resilience controller (WF-SRC) that utilizes a model-assisted safe Deep Reinforcement Learning (DRL) mechanism to reduce the impacts of wildfire-induced disruptions. The WF-SRC continuously monitors and analyzes both the status of the PDS and the spatiotemporal dynamics of wildfires, then executes preemptive actions to prevent wildfires from compromising distribution lines. These actions include optimally dispatching stationary and mobile distributed energy resources (DERs) that operate under a master-slave control scheme. While recent works assume full observability and formulate the PDS resilience problem as a Markov Decision Process (MDP), this approach leads to an impractically large state space and limited realism. In contrast, our approach models the problem as a Partially Observable Markov Decision Process (POMDP). This explicitly captures real-world sensing limitations, such as noisy measurements that arise during extreme events. The POMDP is tackled using an LSTM-TD3 DRL agent, enabling effective sequential decision-making in environments with incomplete information. Using real-world data from Alberta wildfires, simulation results demonstrate the effectiveness of the proposed solution in reducing wildfire impact, optimizing energy distribution, and enhancing robustness to uncertainties, ultimately contributing to a more resilient and proactive power grid.