# Secure and Resilient Renewable Energy Integration with Real-Time Machine Learning

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The variability, uncertainty, and non-synchronous generation of renewable energy sources, such as wind and solar power, impose numerous challenges to large-scale and cost-effective renewable energy integration in transmission and distribution grids. Successful implementation of high penetration of renewable energy relies on interoperable distributed energy resource (DER) grid-support functions with complex control and communication capabilities. The addition of these complex control and communication capabilities considerably increases the vulnerability of the power grids, and made them prone to cyberattacks, which can disrupt normal grid operations by causing system instabilities such as line overloads, frequency and/or voltage violations, voltage collapse, especially during heavy load conditions.

**The goal of this project is to design dynamic control algorithms and low latency intrusion detection systems (IDS) with real-time machine learning (RTML) to improve the security and resilience of power grids with high penetration of renewable energy**. To achieve the long-term (2030) target of extremely high penetration of photo voltaic (PV) energy generation, it is critically important to develop transformative grid operation and scheduling schemes that can increase grid reliability, security, flexibility, and resilience in terms of energy generation, storage, and distribution across multiple space and time scales. The goal is achieved by the following specific objectives.

**First, we propose to improve the reliability and resilience of power grids with high PV penetration by developing dynamic DER control algorithms that can provide uninterrupted grid operations under high impact threats**. The dynamic DER control algorithms need to address two challenges. First, it needs to address the stochastic and intermittent natures of PV sources by developing situation-aware scheduling algorithms that can adaptively coordinate power generations, storage, and distribution among a large number of DERs based on grid conditions, such that the grids can remain normal operation conditions regardless of the weather or attack situations. Second, it can improve the grid resilience by mitigating, surviving, and/or recovering from various adverse events, such as cyberattacks or device failures. The DER control algorithms will be developed by using RTML algorithms that can learn from the environment and make adjustment to grid operations in real time.

**Second, we propose to develop low latency IDS algorithms with RTML. Low latency IDS aims at minimizing detection delay while maintaining high detection accuracy**. This is different from conventional detection methods that focus mainly on detection accuracy. A lower detection delay can shorten the response time, such that remedial actions and/or counter measures can be taken in a timely manner to significantly reduce the damages and economic losses caused by cyberattacks. In order to account for the dynamic grid operation environment due to high penetration of renewable energy, the low latency IDS algorithms will be developed by using RTML, which can dynamically learn the fast variations of the operation environment in real time, thus to make timely decisions. For grids with high PV penetration, one of the important tasks of the RTML algorithm is to distinguish between the impacts of weather change and cyberattacks on sudden grid state changes, and this can be achieved by using a hybrid model- and data-driven approach that relies on both the physical model of the grid and the measurement data collected from the grid.