

## **THE VALUE OF RENEWABLE INTEGRATION STUDIES**

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Power systems around the world are experiencing continuously increasing penetrations of wind and solar power, two renewable energy sources that are variable and uncertain in nature. During the past years, multiple renewable integration studies have been performed to study how the variability and uncertainty of increasing penetrations of wind and solar power will impact bulk power system planning and operations. Each of these studies was planned and designed for different goals and to answer different questions regarding the potential impacts of wind and solar integration. This plenary presentation intends to give an overview of the most relevant renewable integration studies performed by the National Renewable Energy Laboratory (NREL) for power systems in the United States (US) as well as in other regions and countries around the world. Differences in scope, modeling approaches, including optimization algorithms and dynamic simulations, as well as information and data needs, will be discussed. Major insights from the research efforts performed in different renewable integration studies will be presented. These will serve as examples to discuss the value of performing renewable integration studies for power systems that are, or will be, experiencing increasing penetrations of variable and uncertain renewable energy sources. For example, the three phases of the Western Wind and Solar Integration Study were designed to study different impacts of higher penetrations of wind and solar power in the US Western Interconnection. Different modeling approaches led to a range of valuable insights that include the following: the integration of 35% wind and solar energy will not require extensive infrastructure if changes are made to operational practices; the increase in power plant emissions from cycling to accommodate variable renewables is more than offset by the overall reduction of these greenhouse gas emissions; with good system planning, sound engineering practices, and commercially available technologies, the Western Interconnection can withstand the crucial first minute after severe grid disturbances with high penetrations of wind and solar power on the grid. The modeling approaches and results of other renewable integration studies will also be discussed, such as the ones performed for the US Eastern Interconnection, for the Indian power system, and for the islanded power system of the Mexican region of Baja California Sur.