Fractal-Based Cloud Shadow and Irradiance Model for Power System Analysis with High Penetration of Photovoltaics

By

Chengrui Cai

ccai@iastate.edu

http://home.engineering.iastate.edu/~ccai/

Major: Electrical Engineering
Advisor: Prof. Dionysios C. Aliprantis

Defense Date: April 17 (Thursday), 2014, 4 - 7 PM
Location: 2222 Coover, Iowa State University

ABSTRACT

Distributed photovoltaic (PV) power generation systems are being rapidly deployed worldwide, causing technical problems such as reverse power flows, voltage rise and abnormal operation of voltage control devices in distribution feeders, and real and reactive power transients that affect the operation of the bulk transmission system. To fully understand and address these problems, extensive computer simulation studies are required. As a prerequisite, modeling of PV generation with satisfactory spatial and temporal resolution plays a key role. To this end, this dissertation sets forth a fractal-based cloud shadow and irradiance model that can be used to recreate the power generation of rooftop PV systems embedded in a distribution feeder, or that of a utility-scale PV power plant, during days with low-altitude cumulus clouds. Because of its clearly defined edge and the deep shadow it creates, the cumulus cloud is considered as the cloud type that contributes the most to fluctuations of power output from distributed PV systems, which is a primary concern of system engineers. Realistically shaped cumulus cloud shadows are modeled as fractals. Technical details of the model development, validation and tuning are presented. A case study that focuses on impacts to Load Tap Changer actions demonstrates the potential of the developed model in power system analysis with high penetration of photovoltaics.