Takashi Ikegami, Expert Opin Environ Biol 2018, Volume 7
DOI: 10.4172/2325-9655-C4-029

Quantification of wind power output fluctuations and its geographical smoothing effects for power system operations

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Because of unpredictable fluctuations in wind power output caused by sudden changes in weather conditions, operations that balance supply and demand in power systems will gradually become more difficult with the massive deployment of wind power generation. Therefore, it is necessary to quantitatively evaluate wind power output fluctuations in a way that corresponds to frequency controls in power system operations. With an increasing number of wind power generators were installed, these fluctuations and variations with respect to the rated output capacity will decrease because of the geographical smoothing effects, i.e., the output fluctuations of multiple wind turbines will mutually cancel one another. In this study, we have quantitatively evaluated the wind power output fluctuations and its geographical smoothing effects for each power system. We analyzed the actual high time-resolution wind power output data of 57 wind farms in six power system in Japan. We proposed a novel quantitative definition of the output fluctuations associated with the frequency controls of power systems: primary turbine-governor control (TGC), secondary load-frequency control (LFC), and tertiary economic load-dispatch control (EDC). Using this definition to quantify fluctuations demonstrates how each smoothing technique can contribute to reducing the reserve capacity necessary for frequency control in the power system operations. Our proposed definitions for dividing the frequency ranges of the fluctuations were confirmed as a convenient and practical method for quantitatively evaluating the fluctuations and determining the reserve capacity required for stable power system operations. Furthermore, we proposed a novel quantitative method for smoothing effects of fluctuations. We used the exponential parts of the approximation curves of fluctuation ranges with respect to the wind power capacity to evaluate the smoothing effects. Using these exponential parts, we observed that perfect smoothing effects were obtained in the shorter-cycle TGC domain. On the other hand, the smoothing effects of the fluctuations in the EDC domain were observed to be small in all power systems.

Biography

Takashi Ikegami, Ph.D. is an associate professor in the Institute of Engineering at Tokyo University of Agriculture and Technology. His work is centered on developing models for system analysis to massively integrate renewable energy and ensure optimal energy management. Dr. Ikegami received his BEng and MEng in Chemical Systems Engineering from the University of Tokyo, in 2001 and 2003, respectively. He also received Ph.D. in Urban Engineering in 2007 from the University of Tokyo. He was employed by National Institute for Environmental Studies, then assistant professor in the Institute of Industrial Science at the University of Tokyo. He is a member of IEEE.

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