Requirements for DEMO from the Aspect of Mitigation of Adverse Effects on the Electrical Grid

Shutaro TAKEDA, Yasushi YAMAMOTO[1)], Ryuta KASADA[2)], Shigeki SAKURAI and Satoshi KONISHI[2)]

Graduate School of Advanced Integrated Studies in Human Survivability, Kyoto University, Kyoto, Kyoto 606-8306, Japan
[1)]Faculty of Engineering Science, Kansai University, Suita, Osaka 564-8680, Japan
[2)]Institute of Advanced Energy, Kyoto University, Uji, Kyoto 611-0011, Japan

(Received 13 April 2015 / Accepted 4 June 2015)

The adverse effects of DEMO on the future electrical grid due to sudden output interruptions, such as disruptions, were analyzed quantitatively. The results indicated that when considerable percentage of renewables are installed, the power system would experience serious frequency deviations as large as 0.4 Hz, which is greater than the current tolerance, 0.2 Hz. DEMO installation would need an assessment as part of the power system, together with mitigation devices, to be connected to the grid.

Keywords: DEMO design, output interruption, plasma disruption, power system, frequency, battery

DOI: 10.1585/pfr.10.1205070

One of the most important missions of the next fusion plant, DEMO, will be electricity generation. However, there are significant envisioned problems for DEMO: its startup power and the reliability as a source of electricity. When designing DEMO, its compatibility with the electrical grid would be a critical requirement and a limitation. Typical DEMO designs require a few hundreds of MW of power when starting operation, primarily for magnetization of coils and plasma heating and current drive. In addition, unpredictable interruptions of output power due to plasma disruptions and other off-normal events also have to be considered. Since the percentage of renewables will be greater in the future, effects of these disturbances would be greater than currently envisioned. This study assessed the adverse effects of DEMO on the grid quantitatively through a simulation-based case study on Japanese power system of 2040.

The energy mix of 2040 was assumed based on IEA's New Politics scenario [1]. Characteristics of generation fluctuation of renewables were estimated based on AMeDAS statistical data [2,3]. The estimated standard deviations of fluctuations per 10 min were 0.0178 for PV and 0.0083 for wind per rated power. In this study, the utility frequency was chosen as the barometer of impact on the grid. A model was developed based on the Heffron-Philips model to simulate the behavior of the frequency to represent Japanese longitudinal power system comprised of the north, the east and the middle-west system [4]. Validity of the model was evaluated by comparing two reference scenario results with Y-method, the standard simulator in power industry. Both scenario results matched well as shown in Fig. 1.

DEMO was installed to the east system in this study. It was assumed that the generation power would go down from 1.16 GW to zero immediately, based on an envisioned behavior of DEMO in case of plasma disruption [4], assuming the power loss comes from cooling of the blanket that loses neutrons. Since the cooling is expected to happen rapidly, the generator of the plant was assumed to be cut off from the grid immediately.

Output interruptions triggered serious frequency deviations on the east system, where the largest effects were observed during bottom hours (e.g. 5 a.m.) as shown in Fig. 2. The deviations varied on the fluctuation amount of renewables in the last 10 minutes because it reduces spinning reserve of the system. Deviations were greater than the current tolerance, 0.2 Hz [5], but were limited to 0.4 Hz by emergency electric power interchange. The effect of

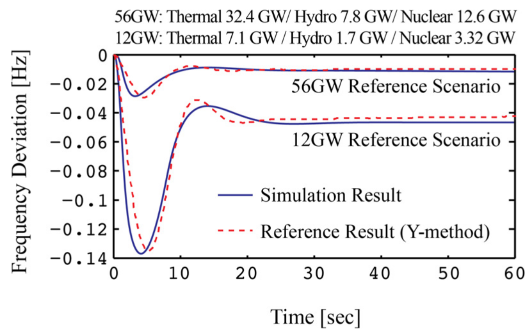

Fig. 1 Comparison of freq. behaviors against the reference simulator.

author's e-mail: takeda.shutarou.55r@st.kyoto-u.ac.jp

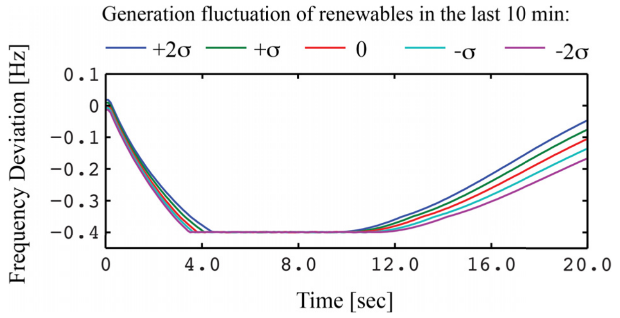

Fig. 2 Freq. deviations of the east system upon an output interruption.

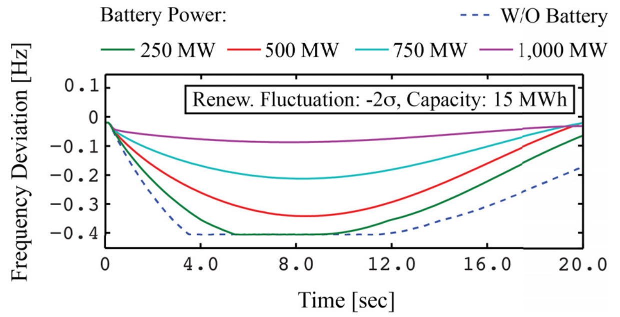

Fig. 3 Freq. deviations of the east system with various batteries.

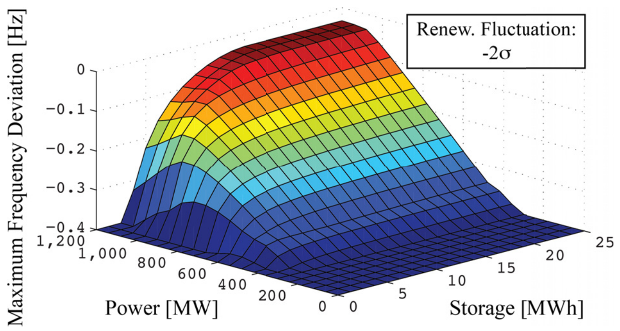

Fig. 4 Max. freq. deviations against various battery specifications.

output interruptions rippled to the north and the middle-west system. These results indicate that an output interruption mitigation device would have to be accompanied with DEMO introduction to the grids with considerable renewable fraction.

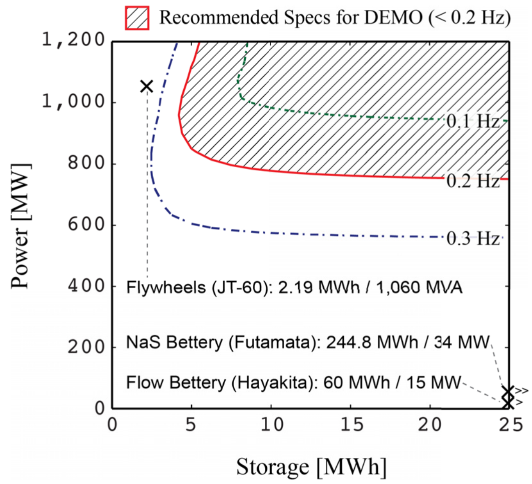

Fig. 5 Recommended battery specifications for DEMO.

One of the candidates is the NaS battery. To assess its effectiveness, a battery model with first order lag of 0.1022 sec was installed in the model. Figure 3 shows the frequency deviations of the system with a battery with 250 - 1,000 MW power. The result indicates that an appropriately sized battery would minimize the deviations in the grid as the mitigation device. The maximum deviations of the grid with a battery with different power output (W) and storage capacity (Wh) are shown in Fig. 4 on the vertical axis. The recommended specification for DEMO is summarized in Fig. 5. Currently there are no such large power storage devices that meet the required specifications. It should also be noted that the DEMO would have adverse effects on start-up where significant amount of reactive power would be involved. Therefore, this paper concludes that considering the stability of the power system, a mitigation device would have to be designed for DEMO to be connected to the electrical grid.

[1] International Energy Agency, *World Energy Outlook 2014* (IEA PUBLICATIONS, Paris, 2014) p.636.
[2] Y. Masaki *et al.*, Phys. Theor. Appl. Climatol. **100.3**, 283 (2009).
[3] D.G. Erbs *et al.*, Solar Energy **28.4**, 293 (1982).
[4] S. Konishi *et al.*, Fusion Eng. Des. **63**, 11 (2002).
[5] T. Sasaki *et al.*, Technical Report of Institute of Electric Engineering **869**, 103 (2002).