Effect of Output Estimation Errors of Vertical Bifacial Photovoltaic Systems for Required Reserve Margin and Unit Commitment

Keito Nishida[1,*], Ryuto Shigenobu[1], Akiko Takahashi[1], Masakazu Ito[1], Kyungsoo Lee[2]

[1]University of Fukui, Japan, [2]Tech University of Korea, Korea
[*]nkd23006@g.u-fukui.ac.jp

In power systems, unit commitment (UC) is important for scheduling synchronous generator (SG) outputs to minimize fuel costs. The photovoltaic (PV) systems pose challenges such as the shortage of reserve margin due to forecast error and reduction of system resilience due to increased peak outputs. In addition, while PV systems enhance economics by lowering fuel usage of the whole power system, the PV operator needs to curtail power when PV output exceeds demand. As a countermeasure, vertical bifacial PV (BiPV) systems have been noted for their effect in shifting peak outputs. However, estimating BiPV output is complex, and errors will be significant. Therefore, while this system mitigates fuel costs, estimation errors reduce the stability of the power system.

This paper applies measured and estimated data of BiPV to UC to verify the impact on fuel costs and power curtailment. Firstly, global horizontal irradiance (GHI), direct normal irradiance (DNI), and diffuse horizontal irradiance (DHI) are measured to estimate BiPV outputs. Next, the front side's direct irradiance is calculated using the Direct Method, while diffuse irradiance is calculated through the Uniform Model, and ground-reflected irradiance by the Uniform Reflection Model. A tilt angle of 90 degrees is set, and each irradiance component totals up to the front side's irradiance, which faces east or west. Concurrently, actual BiPV irradiance is measured on-site for both orientations. The bifaciality of this bifacial module is 75%. Figure 1 shows the measured and estimated irradiance. The BiPV system output is calculated using these data, PV capacity and performance ratios. Finally, the UC determines the optimal output and operational states of SGs to minimize fuel costs by using estimated and measured PV output of each orientation. The objective function minimizes the fuel cost of all SGs and the required reserve margin is set at 3% of demand. The fuel cost and the curtailment energy are shown in Figure 2 and 3. An effect of estimated error to reserve margin at cloudy or rainy day is shown in Figure 4. Figure 2 indicates a difference in fuel cost between using estimated and measured data from 5 GW to 30 GW. Also, it has converged to 1.3×10^{9} [JPY]. Conversely, Figure 3 reveals that the curtailment energy increases with the massive PV systems. On the other hand, Figure 4 shows the effect of the estimated error cannot be ignored and exceeds the required reserve margin at more than a PV capacity of 41 GW. In conclusion, the accuracy of estimation methods needs to be improved. In addition, results suggest that while increasing PV capacity reduces fuel costs, it concurrently heightens the necessity for power curtailment. Thus, the power system needs processes and devices to use this curtailment energy effectively.

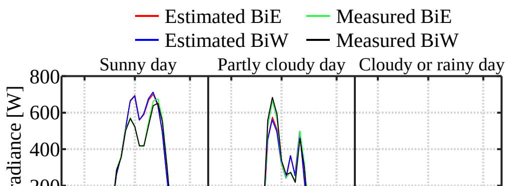

Figure 1: Profile of measured and estimated BiPV output of 3 types of weather.

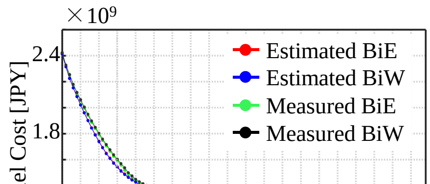

Figure 2: Fuel Cost for each BiPV output on a sunny day according to PV capacity.

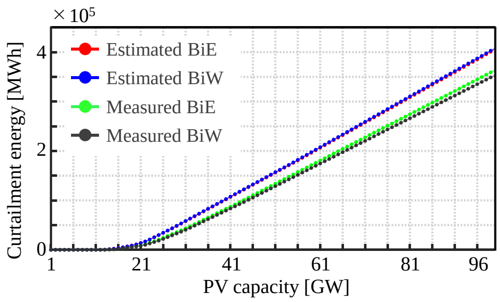

Figure 3: Curtailment energy for each BiPV output on a sunny day according to PV capacity.

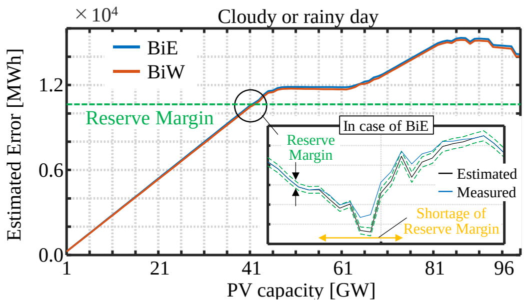

Figure 4: Effect of sum of PV output estimation errors over 24 hours to sum of reserve margin at cloudy or rainy day.