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Wind Tunnel Tests on Ground-Mounted and Roof-Mounted Photovoltaic Array Systems

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Abstract : Solar energy is one of the replaceable choices to reduce the CO2 emission produced by conventional power plants in the modern society. As an island which is frequently visited by strong typhoons and earthquakes, it is an urgent issue for Taiwan to make an effort in revising the local regulations to strengthen the safety design of photovoltaic systems. Currently, the Taiwanese code for wind resistant design of structures does not have a clear explanation on photovoltaic systems, especially when the systems are arranged in arrayed format. Furthermore, when the arrayed photovoltaic system is mounted on the rooftop, the approaching flow is significantly altered by the building and led to different pressure pattern in the different area of the photovoltaic system. In this study, L-shape arrayed photovoltaic system is mounted on the ground of the wind tunnel and then mounted on the building rooftop. The system is consisted of 60 PV models. Each panel model is equivalent to a full size of 3.0 m in depth and 10.0 m in length. Six pressure taps are installed on the upper surface of the panel model and the other six are on the bottom surface to measure the net pressures. Wind attack angle is varied from 0° to 360° in a 10° interval for the worst concern due to wind direction. The sampling rate of the pressure scanning system is set as high enough to precisely estimate the peak pressure and at least 20 samples are recorded for good ensemble average stability. Each sample is equivalent to 10-minute time length in full scale. All the scale factors, including timescale, length scale, and velocity scale, are properly verified by similarity rules in low wind speed wind tunnel environment. The purpose of L-shape arrayed system is for the understanding the pressure characteristics at the corner area. Extreme value analysis is applied to obtain the design pressure coefficient for each net pressure. The commonly utilized Cook-and-Mayne coefficient, 78%, is set to the target non-exceedance probability for design pressure coefficients under Gumbel distribution. Best linear unbiased estimator method is utilized for the Gumbel parameter identification. Careful time moving averaging method is also concerned in data processing. Results show that when the arrayed photovoltaic system is mounted on the ground, the first row of the panels reveals stronger positive pressure than that mounted on the rooftop. Due to the flow separation occurring at the building edge, the first row of the panels on the rooftop is most in negative pressures; the last row, on the other hand, shows positive pressures because of the flow reattachment. Different areas also have different pressure patterns, which corresponds well to the regulations in ASCE7-16 describing the area division for design values. Several minor observations are found according to parametric studies, such as rooftop edge effect, parapet effect, building aspect effect, row interval effect, and so on. General comments are then made for the proposal of regulation revision in Taiwanese code.

Keywords : aerodynamic force coefficient, ground-mounted, roof-mounted, wind tunnel test, photovoltaic
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