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Is behind-the-meter solar an effective way to improve water distribution system resilience?

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Abstract: A water distribution system (WDS) is a vital component of water infrastructure systems. The pump operation in pressurised WDSs usually consumes significant electricity. To reduce pumping-related cost and environmental impact, behind-the-meter solar photovoltaic (BTM solar PV) system is becoming an increasingly popular additional source of energy supply for WDSs. The integration of the BTM solar PV system to WDSs is complex, requiring the consideration of the interaction between the WDS and the solar PV system. Moreover, future changes in water demand and solar PV technology development in terms of unit cost and conversion efficiency further complicate the design of WDSs integrating BTM solar. This research aims to investigate the impact of long-term changes in water demand and solar PV technology development on the co-design of WDSs integrating BTM solar considering system performance in terms of the life cycle cost and grid energy consumption.

In this study, future water demand is assumed to change between -30% to +100% in the next 60 years. Three solar PV technology development conditions are considered: the baseline condition ($T_{const.}$) with the current unit cost and conversion efficiency, the conventional technology ($T_{conv.}$) resulting in a moderate reduction in unit cost and increase in conversion efficiency, and the advanced technology ($T_{adv.}$) resulting in a larger reduction in unit cost and rapid increase in conversion efficiency. In total 15 scenarios considering the different changes in water demand and solar PV technology development have been developed to represent future uncertainty. The integrated system has been optimised under each scenario, and the performance of the design is evaluated across all scenarios. The performance distribution of 3 specific designs obtained under three scenarios with the demand change by +30% and the 3 different solar PV technology development conditions is illustrated in Fig.1: Design 1 from $T_{const.}$, Design 2 from $T_{conv.}$, and Design 3 from $T_{adv.}$, respectively.

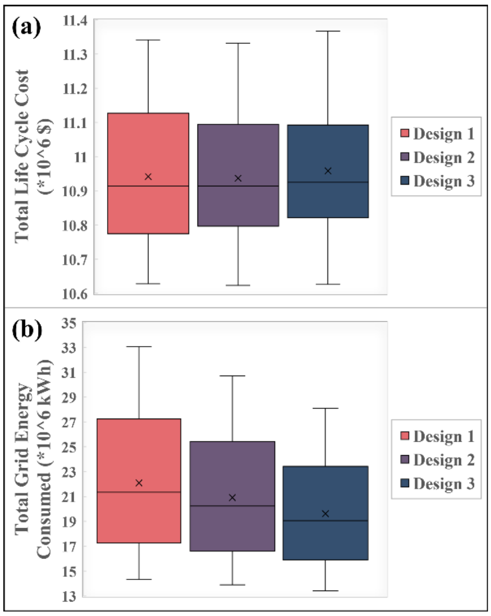

Figure 1. The distribution of (a) total life cycle cost and (b) total grid energy consumed by the 3 specific BTM solar integrated WDS designs across all scenarios: Design 1 obtained from $T_{const.}$, Design 2 obtained from $T_{conv.}$, and Design 3 obtained from T_{adv}

Results show that the potential development in BTM solar technology, i.e., future improvements in the unit cost and conversion efficiency, has a limited impact on the sizing of the pipes and pumps of WDSs. However, the changes in water demand will have a significant impact on the optimal sizing of WDSs. The higher the demand growth, the larger the sizes of pipes and pumps are expected. It is evident from Figure 1 that for the same WDS, more advanced development in solar PV technology leads to more consistent performance (i.e., the narrowed range of values) in terms of cost. More importantly, it leads to much lower grid energy consumed, as well as more consistent energy performance across various water demand conditions. The integration of solar PV systems into WDSs helps to reduce the risk of oversizing WDSs by improving the energy performance of WDSs under changing water demand conditions. The results also highlight the opportunity of improving the future performance of potentially under-sized WDSs through the integration of the BTM solar PV system.

Keywords: *Water distribution system, behind-the-meter solar, water demand uncertainty, technology development uncertainty*