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Control of domestic electric hot water storage tanks for improving PV self-consumption

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Abstract

Australia has become the global leader in rooftop PV installations per capita, with penetration rate exceeding 20% (Clean Energy Regulator, 2019). Market forecasts indicate the high installation rates will persist in the coming years, as solar continues to be the cheapest form of electricity available (Clean Energy Regulator, 2017). Besides various environmental benefits, increasing levels of distributed PV generation is also bringing challenges for our electricity grids which were originally built to support unidirectional energy flow. One of the most imminent challenge with integrating high levels of distributed PV into the grid is maintaining safe voltage and frequency limits, especially in parts with high PV export rates (Stringer, Bruce, & Macgill, 2017). To reduce high PV export rates and cope with the arising challenges, network companies discuss implementing strategies such as: dynamic export limits for existing PV systems, inverter power control/curtailment modes and PV system size limitations for new systems (AEMO, 2017). Beyond these strategies, a simpler, yet more effective solution for reducing PV export rates is to increase PV self-consumption rates in households.

One of the most common methods to improve PV self-consumption rate is to store the excess generation in batteries in chemical energy form during the day and use it later in the afternoon or evening. Although the interest and demand for household batteries has been growing, the current prices makes the investment economically unattractive for most households (Horan, Mcgrath, Santha, & Consulting, 2017). Besides batteries, electro-thermal storage is another alternative where excess PV generation can be stored in thermal energy form during the day and used at a later time (Jack, Suomalainen, Dew, & Eyers, 2018). Appliances for space and domestic hot water heating are perfect candidates for such application. In particular, domestic electric hot water tanks have one of the largest electricity consumption amongst the household appliances, offering large thermal storage capacity. It is estimated that there are more than 1,000,000 households in Australia (~10% of the population) with rooftop PV system and electric hot water storage tank who can potentially utilize their excess PV generation for heating water (BIS Oxford Economics, 2014). This can not only bring financial savings for individual households through the improved PV self-consumption rates, but also help electricity networks in dealing with over voltage problems caused by the increasing levels of rooftop PV exports.

In spite of this great potential, the only major form of electric hot water load control in Australia remains to be the “off-peak controlled load“ which is offered by distribution network service providers (DNSPs) to shift the aggregate electric hot water load to off-peak periods. Other electric hot water load control methods such as diverters and simple timers have been also used to shift electric hot water load to the middle of the day and utilize excess PV generation. However, these systems are very small in number and there isn’t any data or prior reseach which shows the potential benefits and losses of these control methods. Therefore, there is very limited understanding for the potential of using load control methods to shift electric hot water load to the middle of the day and utilize excess PV generation.

To adress this gap, this paper studies a sample of 353 households from Solar Analytics data-base (Solar Analytics, 2019) with 5 minutely rooftop PV generation, household and hot water tank electricity consumption data for the calendar year between 01/03/2018-01/03/2019. Firstly, the electricity consumption of the hot water tanks are characterized in terms of the time of day, weekday/weekend and seasons. Secondly, electric hot water load shifting capacity is discovered for each household. Figure 1 shown below breaks down the shiftable electric hot water load capacity in terms of seasons and weekday/weekends. It is seen that majority of the household (~90%) can potentially provide at least 40% of their daily hot water electric consumption through their excess PV generation throughout the year. A final analysis is carried for understanding the potential financial benefits of electric hot water load shifting to solar times. It is found that household's PV system size, habitual consumption patterns, power rating of the hot water tank and the electricity tariffs have significant impact on these potential benefits. The results can be used to help households in deciding whether they can benefit from such load control product.

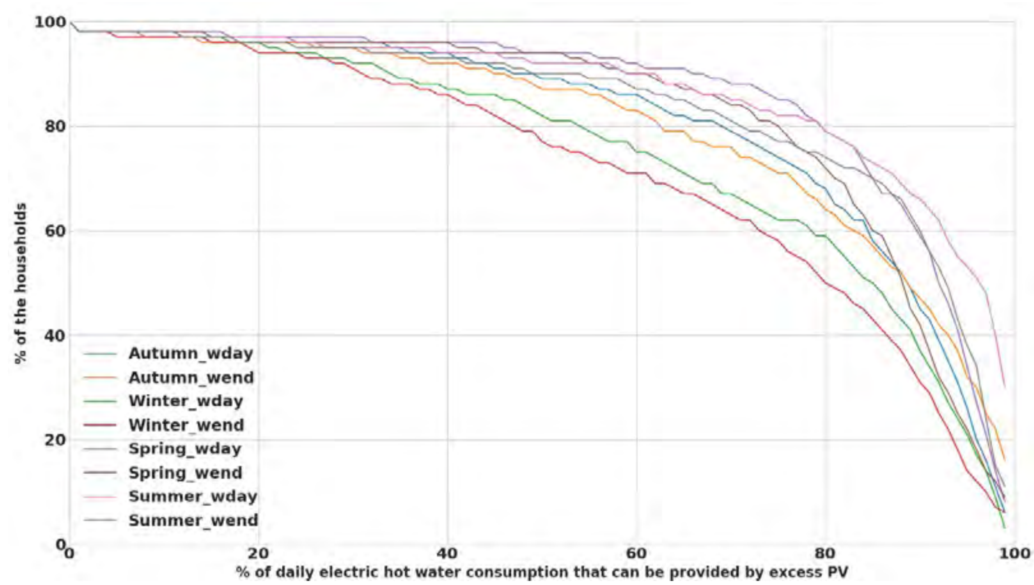

Figure 1 Percentage of shiftable electric hot water load across different seasons and weekend/weekdays

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