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# Using Domestic Hot Water Heaters As Thermal Storage At A Network Scale.

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With the emergence of lower cost photovoltaic components which has led to a greater uptake of electrical grid interactive systems, coupled with historically beneficial feed in tariffs, we now see a situation whereby the grid is struggling to accept greater PV injection due to the inability to match generation and load in quantity and time. The emergence of the Duck Curve phenomena is becoming a limitation for renewable energy. There are a number of solutions proposed that all aim to address the imbalance of load and generation through either load time shifting, storage and on demand power generation. The challenge is to couple load, storage and generation such to minimise the impact on consumers whilst deploying technologies with minimal capital costs that encourage rapid network scale uptake.

Minimising the exportation of site generated power through self-consumption would reduce the magnitude of the duck curve. The consumer is incentivised to do this through feed in tariffs offering prices less than purchased energy prices. When considering the efficiencies of the power transmission it is also shown that self-consumption maximises the power supply efficiency of site generated PV power.

Water having a high thermal mass and a domestic demand in the form of hot water consumes a significant portion of total household energy. It is also considered a viable and cost effective energy storage option that is safe, inexpensive and readily available. The challenge is to match the site PV generation, all other dwelling electrical loads and vary the hot water electrical load to match the excessive power generation that would otherwise be exported to the grid.

A system that monitors in real time the power interaction of the dwelling and the grid can determine when net PV power is being delivered to be grid. If the load of a domestic hot water unit is modulated such that the exported power is zero, then maximum self-consumption has occurred.

The practicalities of supplying hot water on demand to a dwelling leads to a consideration that there are times that insufficient site generated PV power is available to meet the entire household energy demand. In this scenario purchased energy from the grid must be consumed to supply the dwelling demand (this can including hot water heater energy consumption). Obviously the consumption of purchased energy would be preferred to be minimal, both from a customer financial point of view and overall hot water supply efficiency. The supply of electricity to achieve the minimum amenity of hot water demand can therefore be made up from both PV and grid imported power where PV is insufficient to meet the required load.

If by segmenting the water heater into an upper and lower heating position, supply of the minimum amenity hot water demand using the upper heating unit can be achieved, leaving capacity for the lower heating unit to store excess PV. If the power capacity of the upper heating unit is set to 3.6kW and allowed to heat to a capacity of 150L of water to 60C whilst on a continuous tariff this allows a load supply of 24 minutes at a flow rate of 12l/m (40C tempered water at point of discharge with a cold supply temperature of 10C). This supply is deemed capable of meeting the peak demands of a typical dwelling with a recharge period of 2.4hrs which is less than the dwell time to the next peak demand.

To negate or minimise the use of purchased energy, energy at power levels less than 3.6kW must be stored and must be stored at larger volumes than 150L. Storage of hot water at higher temperatures than 60C also increase the capacity of energy storage in the water heater further however does increase the standing losses of the water heater. Therefore storage capacity is made up of volume at temperature and both metrics need to be individually controlled.

To increase the solar gain capability of the water heater, the heating phases can therefore be:-

1. Upper heating unit at fixed capacity of 3.6kW heats 150L of water to 60C using a combination of net PV power and purchased energy.
2. Lower heating unit at modulated capacity up to 3.6kW heats the entire heater (300L) to 60C using only net PV power.
3. Upper heating unit at modulated capacity up to 3.6kW heats 150L of water to 80C using only net PV power.
4. Lower heating unit at modulated capacity up to 3.6kW heats entire heater (300L) to 80C using only net PV power.

Using the same cold water temperature of 10C, negating standing losses from water heater and assuming heating phase 1 above is 50% net PV and 50% purchased energy, the heater COP is therefore 5.6 when the heater is fully charged. Storage capacity of 300L at 80C is shown sufficient with no incremental solar gain for many days before purchased energy is required.

Using thermal storage in a domestic hot water heater to maximise site generated PV power self-consumption, it is shown that heater control logic and storage capacity (in volume and energy) need to be carefully considered to ensure hot water loads can be met with no reduction in hot water delivery performance.