Solar-powered Heat Pumps with Energy Storage Systems for Australian Houses

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INTRODUCTION: Climate change has been a critical challenge faced by our world [1, 2]. Non-renewable energy sources accounted for about 73% of the world's electricity generation in 2019 [3]. In Australia, 11% of the country's total energy consumption is represented by the residential sector [4]. Space heating, space cooling, and domestic hot water (DHW) heating contribute about 65% of total energy consumption in Australian households [5]. Fortunately, Australian households are reaching a 25% mark of solar photovoltaic (PV) installation on rooftops. Nevertheless, a substantial amount of PV-generated power remains unused within the household and is also unwanted by the power authorities to be sent back into the grid. Therefore, this research proposes a new service system by which the self-consumption of PV-generated energy can be increased. Heat pumps coupled with thermal energy storage and electric batteries are a promising solution to increasing the self-consumption of PV energy. The topic of sizing the heat pump, solar PV array, electric batteries, and thermal energy storage remains of interest in the solution towards a net-zero energy building (NZEB). Therefore, this research aims to propose a method for sizing the combined system of heat pump, water storage tanks, solar PV array, and electric batteries to satisfy the electrical and thermal energy loads of Australian households.

METHODS: A case study house, which has been monitored and measured is applied towards the development of a sizing method. This study determines the household electrical energy loads by applying the actual energy data from an existing PV system, as well as the Smart Meter data, which records energy flows to and from the grid. A simulation model is developed using AccuRate® software to obtain house conditioning loads. The sizing of the combined system considers water storage tanks, heat pumps, PV array, and batteries for optimising energy performance.

RESULTS: Smart Meter data and the use of AccuRate® software allow for an accurate estimation of annual hourly electrical and thermal energy loads in Australian households. The sizing of the combined system consisting of water storage tanks, heat pumps, solar PV array and battery can be estimated accordingly. In addition, optimization strategies are made for decision-making on appropriate system operation, energy storage and use based on maximizing the PV self-consumption rate.

CONCLUSIONS: This research will provide the method necessary to better understand the sizing of the combined system consisting of heat pumps, water storage tanks, solar PV array, and batteries for households. In addition, this study plans to develop an optimization strategy to make best decisions about system operation, energy storage, and use. This study paves the way for further development of combined systems, including water storage tanks, heat pumps, solar PV, and electric batteries. It helps increase the PV self-consumption in households and has the implication for realizing the NZEB concept, thus reducing carbon emissions and achieving a carbon-neutral environment.

REFERENCES:

[1] Langer, L. and T. Volling, An optimal home energy management system for modulating heat pumps and photovoltaic systems. Applied Energy, 2020. 278.
[2] Bee, E., et al., Air-source heat pump and photovoltaic systems for residential heating and cooling: Potential of self-consumption in different European climates. Building Simulation, 2019. 12(3): p. 453-463.
[3] IEA. https://www.iea.org/reports/electricity-information-overview/electricity-production. 2021 [cited 2021 27 March].
[4] AEU. Australian Energy Update. 2020 [cited 2021 7 June 2021]; Available from: https://www.energy.gov.au/sites/default/files/Australian%20Energy%20Statistics%202020%20Energy%20Update%20Report_0.pdf.
[5] ER. Space heating and cooling. 2014 [cited 2021 7 June 2021]; Available from: http://www.energyrating.gov.au/products/space-heating-and-cooling.