

Shifting Behavior, Shaping Grids: Appliance-Level Residential Demand Response

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Abstract

With the growing share of intermittent renewable energy generation, balancing supply and demand is becoming increasingly challenging, hindering net load leveling. In particular, sharp increases in residential electricity demand during the evening, when solar generation declines rapidly, lead to significant net load surges. Consequently, demand response (DR) programs have become increasingly important. These programs primarily aim to reduce peak load and level overall load. However, existing studies have predominantly focused on peak load reduction, with relatively limited consideration given to load leveling. This study analyzes the minimum compensation required for residential DR participation, referred to as willingness-to-accept (WTA), using survey data. Additionally, patterns of load reduction and shifting across household appliances are evaluated. The findings reveal significant differences in WTA across different appliances, as well as differences in their effectiveness for peak demand reduction and load leveling. Notably, dishwashers and dryers play a key role when usage times are shifted, whereas washing machines and rice cookers have a greater impact during load shifting. A simulation of an actual Korean DR program, based on these findings, indicates that a compensation rate of 1,500 KRW/kWh (USD 1.03/kWh) may inadvertently create new peak loads. This study underscores the need to redesign the existing compensation scheme and implement policy adjustments to ensure power system stability by shifting appliance load reductions to appropriate time periods.