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Supermarket Virtual Power Plants

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INTRODUCTION

MOTIVATION

- Recent changes, like penetration of renewable energy sources, electric vehicles, distributed generation, ageing infrastructure and increased demand, have created the need for a more effective management of the existing electricity networks.
- Demand Response (DR) emerged due to the need for more flexible loads and as a solution for peak demand reductions and grid frequency stability.

RESEARCH GOALS

- Plan an ideal DR strategy by identifying load flexibility and consumption patterns of the retail estate.
- Investigate charges for the use of the local distribution and the national transmission networks, examine their effect on costs and suggest load reduction actions to decrease these delivery charges for retailers.

BACKGROUND

In UK supermarkets, more than 70% of the energy consumed is electricity, the majority of which is used to drive the refrigeration equipment in the store, while the remainder is used for lighting, HVAC, baking and other ancillary services. A recent study made on a new store of one of the UK's largest grocers found that refrigeration with 39%, HVAC with 10% and lighting with 32% form the greatest part of a typical weekday's power consumption [1].

This reveals the potential of DR deployment on supermarkets, since key loads like HVAC, lighting and mainly refrigeration are systems that can offer valuable ancillary services to the grid with the form of considerable power demand reductions. Moreover, it can become obvious how enhanced the demand reduction can become if many highly energy intensive loads within a number of supermarkets are aggregated.

RESULTS

LOAD FLEXIBILITY CHARACTERISATION BY IDENTIFYING SEASONAL LOAD CONSUMPTION PATTERNS

- ✓ Half-hourly consumption data retrieved from Sainsbury's energy database for one year (March 2012 – February 2013).
- ✓ Three different store categories, referring to square footage, used for the aggregation process.
- ✓ Three test stores chosen for each category.
- ✓ 400 Sainsbury's stores finally aggregated.

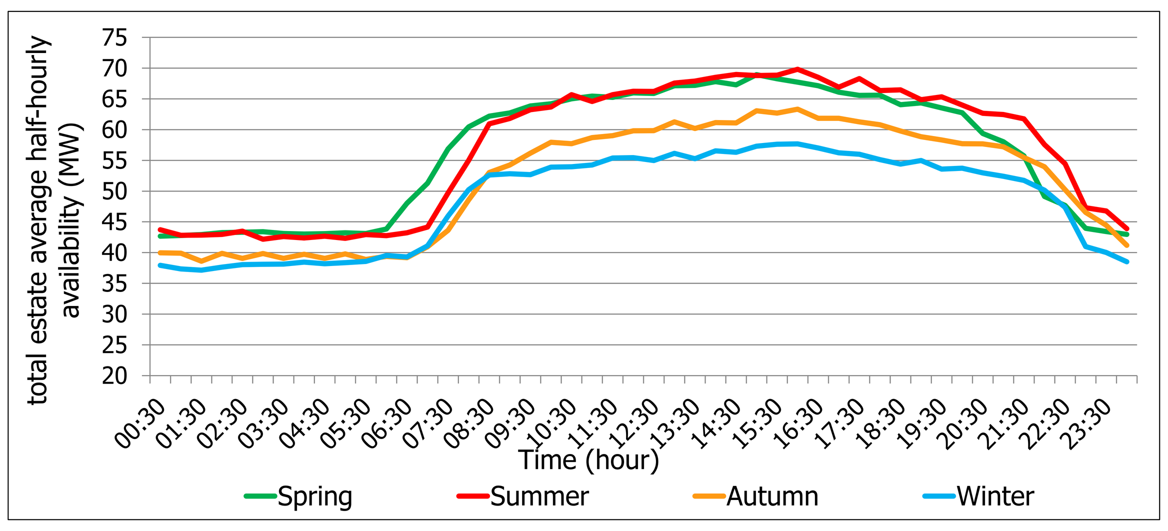

Figure 1. Total estate seasonal half-hourly availability in MW

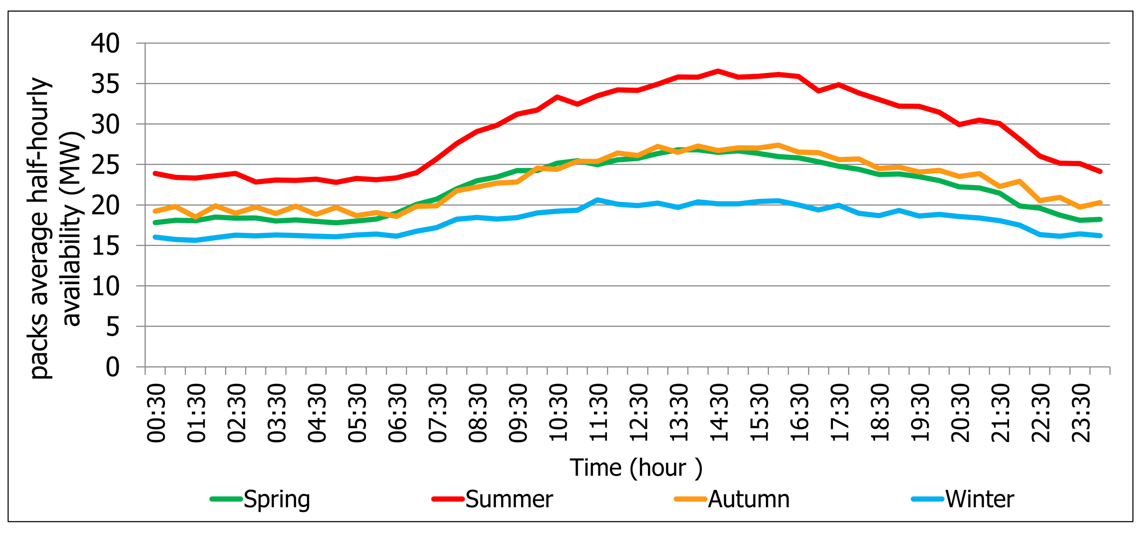

Figure 2. Refrigeration packs aggregated seasonal half-hourly availability in MW

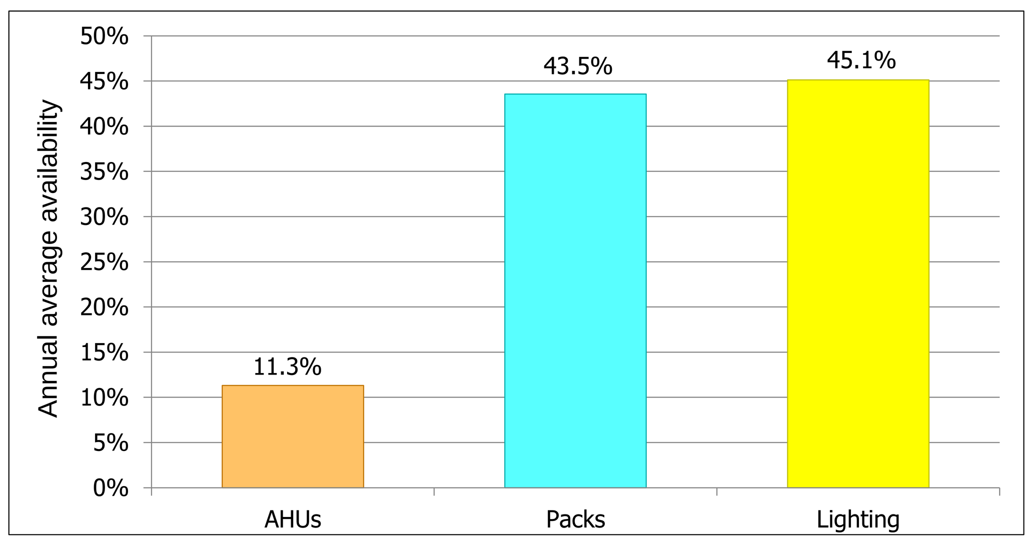

Figure 3. AHUs, packs and lighting system annual average availability as a percentage share of total flexible load

The 400 Sainsbury's stores can potentially make available:
- a constant capacity of 40 MW throughout the entire year
- 55 MW and 60 MW on average during winter and autumn trading hours
- 67 MW on average in spring and summer.

High availability in summer (up to 35 MW) as compared to packs availability during winter months (with maximum capacity of 20 MW).

- The refrigeration packs can contribute in the estate's flexible capacity with 43.5% on average.
- Only an 11% is attributed to the AHUs operation.
- Lighting contributes with 45%.

DUoS UNIT CHARGES

Purpose of what-if analysis: Illustrate the effect high and long red time band unit charges can have on the variable part of Distribution Use of System (DUoS) costs.

METHODOLOGY
- ✓ Annual half-hourly electricity consumption of one Sainsbury's store assumed constant.
- ✓ Six scenarios with different DUoS unit rates assumed, taken from DNOs' charging statements and Sainsbury's datasheets.

RESULTS
- ❑ The North realized higher red time band charges as compared to the South East between 2010-2013.
- ❑ Remarkable difference attributed not only to high DUoS unit charges of SSE, but also to long "red hours" applied in the North.

Key actions to reduce DUoS costs
- Reduce electricity consumption during the red time band, by adjusting the most flexible loads
- Reduce reactive power consumption by improving the site's power factor
- Reduce the Maximum Import Capacity (MIC) by setting it with reference to the level of the site's maximum demand

TRIAD CHARGES

Purpose of Triad charges scenarios: Identify how different zonal tariffs, Loss Adjustment Factors (LAFs) and average consumption on Triad days can affect the final Triad charge.

METHODOLOGY
- ✓ Two stores of similar size and LAF chosen.
- ✓ Located in two different demand zones, and in different DNO areas as a consequence (one in London and one in Scotland).

RESULTS
- ❑ The zonal tariff is what makes the difference in the final Triad charge figure.
- ❑ The London store's Triad charges were 3-10 times higher than those of the store in Scotland.

Guidelines to reduce Triad costs
- Adapt energy checklist with "Make sure" activities to turn off equipment not in use
- Include refrigeration system in energy checklist by carefully designing an approach similar to that of DR according to a set of implications set by occupants.
- Run on-site generators

CONCLUSIONS

- Compressor packs of the refrigeration system are highly energy intensive loads presenting a considerable opportunity for retail stores to offer ancillary services to the grid.
- Serious roadmap should be designed to address electricity consumption reduction during peak hours, so as to reduce both DUoS and Triad charges.

REFERENCES

[1] Acha, S., Shah, N., Ashford J. & Penfold D. (2012). Optimal Lighting Control Strategies in Supermarkets for Energy Efficiency Applications via Digital Dimmable Technology. In *ECOS 2012 - International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems*. Perugia, Italy.