THE CARBON AND ECONOMIC IMPACTS OF ACTIVE NETWORK MANAGEMENT ON LOCAL ENERGY SYSTEMS

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Overview

In many countries, including the UK, there is a move towards decarbonising energy at the local level, with holistic local energy strategies that include heat, transport and electricity. The starting point for this has been an increase in the installed capacity of distributed generation (DG) from renewable energy resources in distribution networks. In order to accommodate these higher capacities on existing networks 'connect-and-manage' systems are being developed that use Active Network Management (ANM) [1].

The trend of increasing the connected capacity of renewable energy in distribution networks is based on an underlying assumption that it will have a positive and cumulative effect on the reduction of greenhouse gases (carbon) from the energy system, while also achieving a viable return on investment. Existing estimates of carbon reduction are, however, typically based on average values that disguise complex temporal variations affecting potential emissions reductions. ANM techniques such as curtailment, adaptive power factor control (PFC) and coordinated voltage control (CVC) alter significantly the temporal profile of distribution network power flows and energy losses.

Research on the marginal carbon emissions of demand fluctuations on the GB transmission network has identified substantial temporal variations [2, 3]. The values and patterns depend strongly upon the fluctuation of total demand, but are also affected by carbon pricing and its resulting effects on the merit-order of competing fuels [3, 4]. This research combines data from analysis of marginal carbon with outputs from a power flow analysis to investigate the carbon reduction of DG with various ANM strategies. The impacts of carbon pricing, the loss of potential revenue due to curtailment, and the corresponding investment implications are also investigated. While the case study scenario and carbon data are for the GB system, it is expected that the techniques developed here will be transferrable to local energy systems around the world.

Methods

An existing time-sequential AC Optimal Power Flow (OPF) technique is used to reconstruct the time series of real power consumption, generation and losses at the network bulk supply point of a generic UK distribution system [5]. The DG is represented by wind farms located across two geographic zones. The wind farm resource is expected to be broadly consistent across each zone.

Five different conditions are modelled: 'fit-and-forget', curtailment, curtailment with adaptive PFC, curtailment with CVC and curtailment with both PFC and CVC (the latter four are all ANM strategies). The maximum installed capacity for each scenario was determined from Ochoa et al. [1]. As DG is not currently subject to economic dispatch in GB, it is assumed that the dispatch is purely technical. (This is expected to change as British Distribution Network Operators transition to Distribution System Operators, but that is outside the scope of this research.) The network power flows are simulated for a single year using half-hourly profiles of demand and potential wind generation across for each zone.

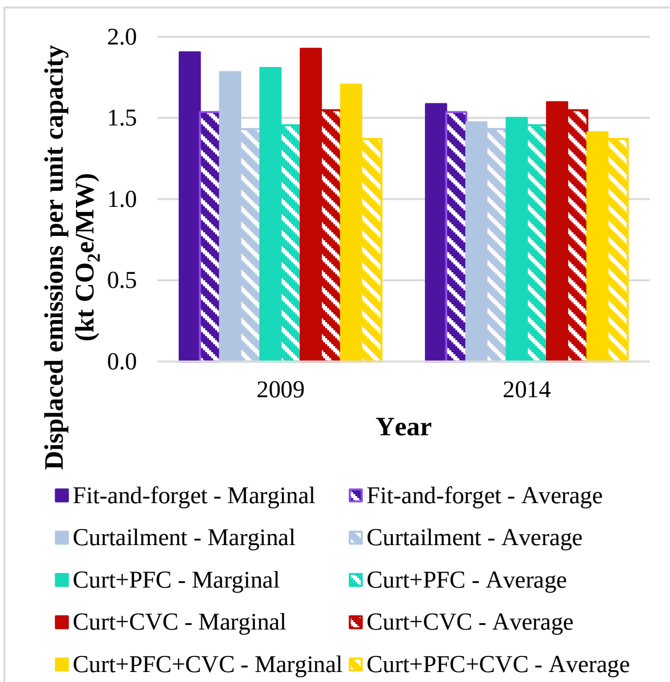

Figure 1 - Emissions displacement of DG with ANM per unit installed capacity

The carbon reduction for each scenario is then calculated based on the difference in active power from the no DG case. Seasonal and diurnal time-sequential marginal carbon emissions factors are calculated from historical GB data using regression methods described in Thomson et al. [3]. The implications of using time-varying marginal emissions data are assessed by comparing the results with those calculated from average emissions [6], and the links to carbon pricing mechanisms, such as the EU Emissions Trading Scheme and the UK Carbon Price Support are also investigated. The potential to apply values from Chyong et al. [4] to better quantify the impacts of carbon pricing on the carbon reduction efficacy of ANM strategies is also investigated.

Results

Preliminary results (Figure 1) indicate that the use of temporally-detailed marginal emissions data generally provides more optimistic estimates of carbon reduction than average data for ANM strategies. This effect is much smaller, however, with data from years such as 2014; it is likely that this is due to the shape of diurnal fluctuations in emissions inverting in this year due partially to relatively low carbon prices.

It can also be seen that the solution with no ANM (fit-and-forget) appears to have almost the best emissions displacement per unit capacity, but this has the lowest installed capacity, and therefore lowest production and smallest carbon reduction. This is illustrated in a review of the emissions reduction relative to the project value (Figure 2), based on estimated cost and price data [7, 8], which shows that some ANM will improve the carbon reduction and revenue.

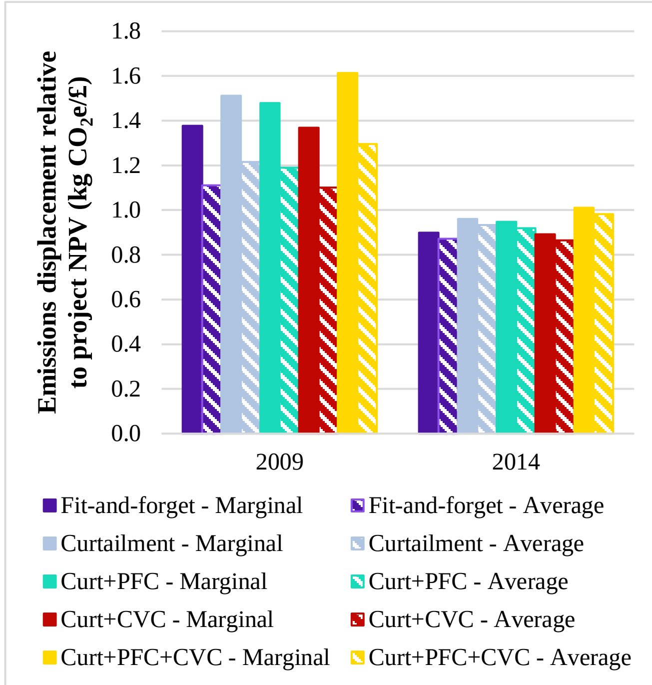

Figure 2 - Emissions displacement relative to wind farm value

Conclusions

This analysis shows that the carbon reduction estimates based on average emissions factors disguise some of the impacts of temporal variation in emissions. Results based on temporally-detailed marginal values reach different conclusions on the value of ANM strategies, and demonstrate an apparent link between emissions reduction and carbon pricing. Further developments of this research will investigate the interaction between national carbon pricing mechanisms and low carbon local energy systems in more detail, and the implications on investment.

References

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