15th EAWE PhD Seminar on Wind Energy
29–31 October 2019
Centrale Nantes, France

Multi-resource Multi-Period Optimal Power Flow for a Rural Orkney Distribution Network

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Keywords: Hybrid Generation, Active Network Management

1 Introduction

The rapid deployment of renewable generation in the last two decades has seen the introduction of power sources on both transmission and distribution levels. Previously, power flowed strictly from supply to demand but distributed generators (DGs) have transformed the structure of distribution networks (DN). Alongside bi-directional power flow, voltage rise and increased fault level have been identified as key issues that DGs poses to network security and stability [1].

Distribution network operators (DNO) have historically connected DGs with a 'fit and forget' approach: generator units are limited so that when connected they can be left to operate uncontrolled. Capacity was allocated according to often irregular worst case scenarios, where low demand coincides with high generation, making inefficient use of the network. The fault in this approach has been recognised and the potential to make better use of the network by using network management techniques has been reviewed [2].

Hybrid generation offers a route to maximise DG production. The time varying nature of renewable resources force unpredictable and uncontrollable generation peaks and troughs. Peaks which combine with periods of low demand define the 'worst case scenarios' that determine the capacity DNOs are willing to connect. If the same DG capacity can be composed of resources with different profiles, either resulting from temporal or spatial differences, the individual extreme peaks can be supressed and network limits might be avoided. A DNO could then connect more capacity.

2 Method

This case study builds on the multi-resource multi-period AC optimal power flow (OPF), designed and used in [3], whose objective function is to maximise the energy production from DGs. A typical rural UK distribution network is simulated, with 5 buses each subject to a load, and two of these buses available for generation.

The optimisation is subject to active and reactive nodal power balances and voltage and power flow limits according to standard grid codes and component ratings. The AC OPF simulates combinations of generator and control technologies to compare the connected capacity and energy delivered for each configuration. The trialled control schemes are active output control (AOC), coordinated voltage control (CVC) and power factor control (PFC).

Generation profiles are built for one year from reanalysis datasets of wind, wave and tidal parameters. The semi-diurnal variation of the tidal profile is uncorrelated with either of the other profiles, which have high cross-correlation between one another at a peak lag of 6 hours. A demand profile for a rural distribution network is used to find the coincident hours of every unique combination with generation. This bi-/tri/multivariate distribution approach reduces the computational effort of the optimisation significantly and identifies the "worst case scenarios" that previously constrained the connected capacity.

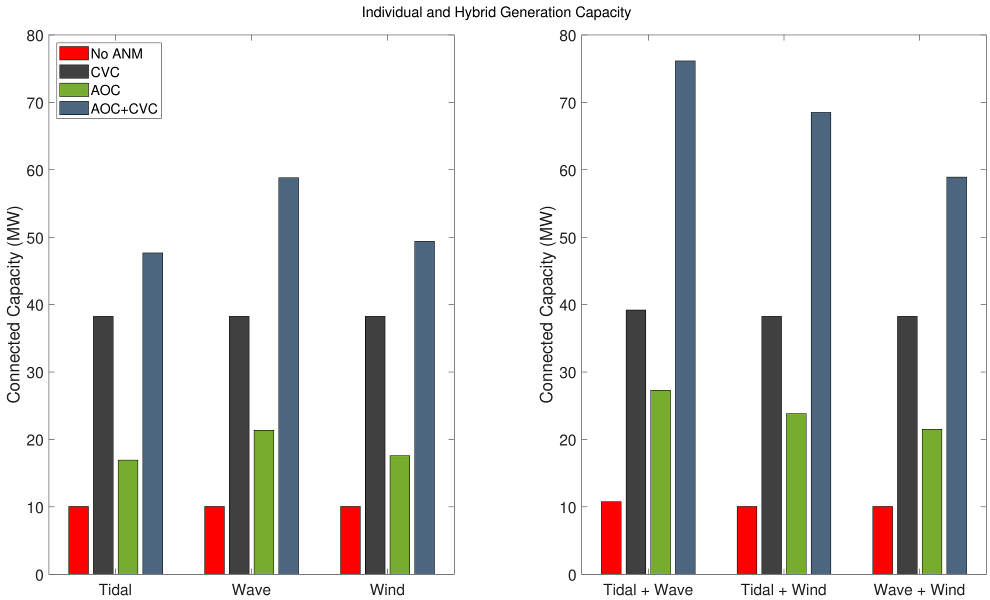

Figure 1: Installed capacity of single or hybrid generation networks under a range of active network management schemes. The available resources are indicated on the x-axis and the control scheme used is indicated by the colour of the bar.

3 Results and Discussion

Networks with access to only one of the generating technologies benefit from the introduction of CVC and PFC, which are capable of reducing the prevalent voltage constraints and increasing connected capacity. When a network has access to multiple resources, AOC is key to increase capacity and energy delivery, by cutting out rare worst case events. In combination with CVC, AOC is capable of increasing the connected capacity and the energy delivered by hybrid networks considerably (figure 1).

High wind and wave generation, expected to offer useful complementarity [4], coincides with low demand too often so that other hybrid configurations are preferred. Networks with three generating technologies cannot connect more capacity than those with two as the final generation profile increases the number of hours where high generation and low demand coincide. However, the complementary generation profiles achieve similar energy delivery, particularly when CVC is not available to the network.

References

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