Towards HIGH PENETRATION and FIRM POWER from WIND ENERGY (FIRMWIND)

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Summary:

The ‚FIRMWIND‘ collaborative project has been performed by partners in UK, Germany and Norway and has been partly funded by the European Commission. FIRMWIND is looking at how, by taking a non-conventional view of the grid network, much higher wind penetration levels might be achieved. The project, via case study, is looking at how various holistic control strategies might allow high wind penetration and high capacity credit at the distribution system level. The paper gives an overview of the project and presents the very interesting results of two case studies of Heimaey in Iceland and Western Isles in Scotland, where it could be shown how provision of storage, and adoption of cost-based dispatch strategies can increase wind penetration and confer useful capacity credit at the distribution system level.

1 Introduction

Many network operators are reluctant to accept significant quantities of wind energy onto their networks. Concerns relate to network stability, network control and guaranteeing supply. It is hypothesised that, by introducing storage and load control onto the system in tandem with wind and by applying suitable holistic control strategies, increased wind penetration levels and capacity credits can be made possible. The project is focused at the local, distribution level and aims to:

- Quantify improvements to wind penetration made possible by the introduction of various energy storage and load management options
- Quantify the change to capacity credit made possible by these options and to study how this changes as the wind capacity on the system increases
- Technically assess how this integrated approach would enable wind to produce firm power and hence reduce or obviate dependence on interconnection capacity.

Within the project a suitable time-stepping and optimising load flow analysis tool was developed with dynamic updating of short-run marginal cost information for the various types of “device” that are being modelled. Storage, load control and power side control technologies were reviewed and characterised. The aim was to collect cost information (capital, ongoing-fixed, and ongoing-variable) and technical data on how individual device types interact in a parameter-dependent manner with the relevant nodal network voltage and active and reactive power flows. Apart from generic types of wind turbine, the project has also reviewed various storage technologies and distributed load deferral technologies. Two case study locations have been identified for in-depth analysis. These are the island of Heimaey off the south coast of Iceland and the Western Isles of Scotland. These case studies represent different scales of demand and differing social requirements. Very interesting results were coming out from these two case studies. One of the key conclusions is that a modest amount of storage can have a very valuable role in increasing the conferred capacity credit of wind. How that store is controlled is vital to the success, and taking a load-smoothing approach can be far more successful in reducing dependence on the grid that trying to use the store to compensate for windless periods.

Partners of the Firmwind project:

- Renewable Energy Systems Ltd (UK)
- Deutsches Windenergie – Institut GmbH (Germany)
- SINTEF Energy Research (Norway)
- Econnect Ltd (UK)
- Proven Enegineering Products (UK),
- Bremer Institut für Betriebstechnik und Angewandte Arbeitswissenschaft an der Universität Bremen (Germany)

2 Definitions

Local Wind Energy Penetration

LWEP is a measure of how much of local demand over a year is met by wind. It can be defined as:

$$LWEP = {}^{E_W}\!/\!_{E_D}$$

E_W is annual energy supplied by wind,
E_D is annual energy consumed by demand.

But, in a system with dispatch management of all elements (grid in-feed, wind and storage), a more useful definition, which reflects the degree to which energy consumed by customers is *not supplied by the grid* is:

$$LWEP = 1 - \left({}^{E_G}\!/\!_{E_D} \right)$$

E_G is annual energy imported from grid.

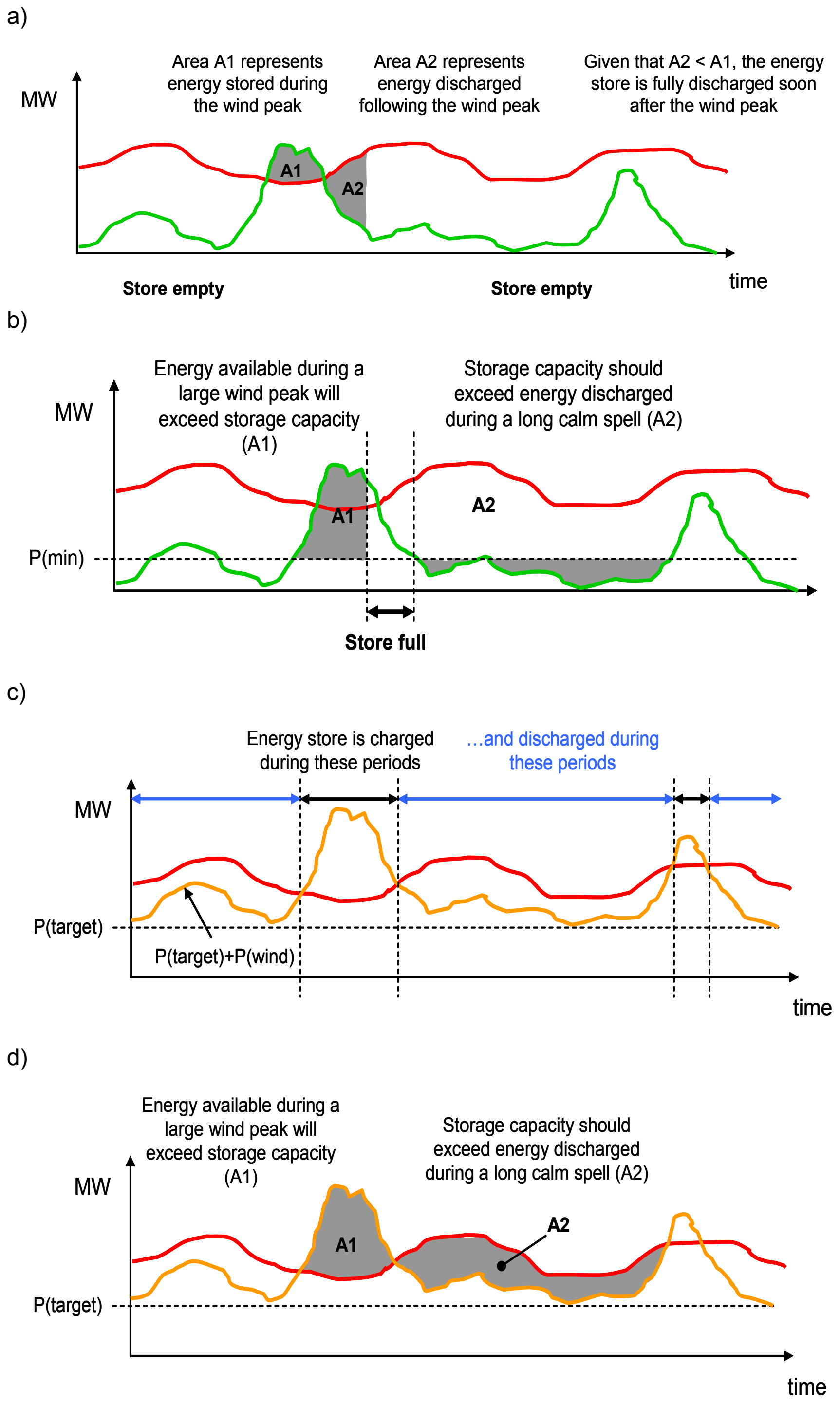

Figure 1: Different dispatch strategies:
a): simple, but ineffective , b): storage is used to smoth wind output

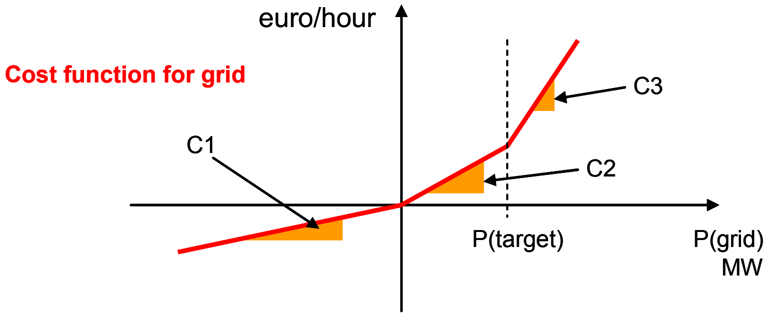

Figure 2: Optimized cost function definition of the optimal power flow

Local Wind Capacity Credit

LWCC is a measure of the wind generation that can be relied upon at time of peak load.

It is defined as the reliable level output of wind generators at the times of maximum demand as a percentage of wind capacity.

In practice, a more useful definition is the level by which 100% reliance on infeed can be reduced:

$$LWCC = {MIN(P_D - P_G)_{PD}}\Big/{C_W}$$

P_D is peak power demand,
P_G is power supplied from grid,
C_W is generation rating of wind plant

The difference between the quantities P_D and P_G being evaluated at times of peak demand.

3 Modelling

A program suite based on time-stepping, optimal power flow (OPF) strategies has been developed.

Based on short-run marginal costs of dispatch, the OPF algorithm selects the most appropriate plant mix at every time step.

The model can handle multiple generation sources, storage and load control.

The model can simulate a full grid network.

Grid constraints, such as voltage limits, can be fully simulated and be taken into account when choosing the dispatch profile.

A module has been developed to synthesise spatially and temporally realistic time series from basic wind statistics.

4 Dispatch Strategies

Referring to Figure 1a, a simple, but ineffective dispatch strategy for wind (green) is to divert to store any excess over load to store, and to recover when wind falls below load. This increases energy penetration, but does nothing for capacity credit as storage is not always available when needed.

An alternative strategy, independent of demand level, involves using storage to smooth the wind output. Wind peaks are sent to store when they exceed a threshold value, P(min); stored energy is recovered when wind falls below this threshold value, see figure 1b). If successful, P(min) will represent the conferred capacity credit.

Weaknesses are that turbine power will sometimes go to store when it might better meet demand and vice-versa. The grid capacity required may not be reduced as well as it might.

A better approach is to use the store and wind together to smooth the net load, see figure 1c, d.

When P(target)+P(wind) exceeds P(load), the ‘excess’ energy is used to charge the energy store. When P(target)+P(wind) falls below P(load), the store is discharged to make up the difference. P(target) is chosen as the grid import level beyond which the local network should not draw.

The following rules-of-thumb have been developed:

- For optimal performance P(target) should be varied seasonally/monthly and set to the average load level net of the average wind production level.
- The charge rating for the store should be roughly the average wind production and the discharge roughly half of this (e.g. for the windy Western Isles, each 1MW of wind should be matched by 0.4MW of charge rating and 0.2MW of discharge rating). The storage capacity should be roughly 30 hours at full charge rate (i.e. in this case 12MWh) or 60 hours of discharge, this being about 3 days i.e. the maximum windless period expected from weather system considerations.

This strategy lends itself to the OPF dispatch model and use of short-run cost functions.

Grid cost functions are (see figure 2):

- A low cost (C1) for exports
- A low cost (C2) for import up to P(target)
- A high cost (C3) for imports over P(target)

The storage cost function is chosen to lie between C2 and C3.

5 Case Studies

Two case studies have been simulated and analysed.

Heimaey, a small island connected of 4,000 inhabitants off the SW coast of Iceland.

Lewis/Harris, part of the Scottish Western Isles, having a 20,000 population.

Both islands are connected to their respective mainland grids by submarine cable.

The project has investigated how, by use of storage and prudent control, the islands can reduce dependence on these links.

For the Western Isles, the network has been modelled with wind at distributed locations.

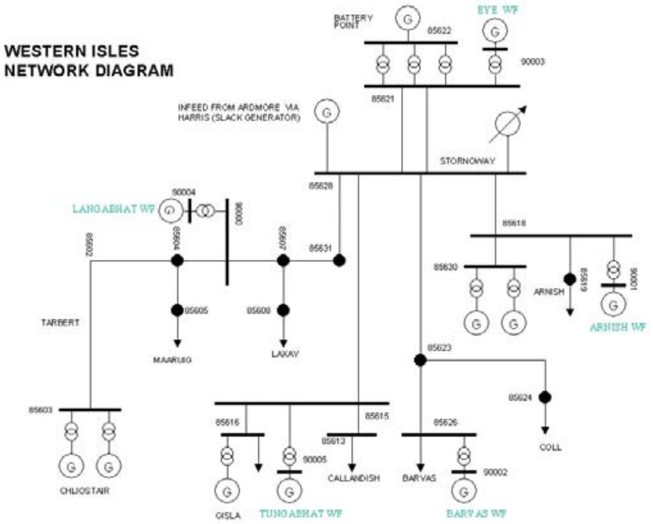

Figure 3: Network of the Western Isles case study for optimal power flow.

6 Conclusions

Without FIRMWIND dispatch control, case data shows that wind in a local system has zero capacity credit.

Introduction of modest storage (regenerative chemical storage has been identified as having the required characteristics), together with relatively simple control can confer useful capacity credit at justifiable cost.

How that store is controlled is vital to the success, and taking a load-smoothing approach can be far more successful in reducing dependence on the grid that trying to use the store to compensate for windless periods.

7 References

[1] FIRMWIND project: ERK5-CT1999-00018; Programme : “Energy, Environment and Sustainability”