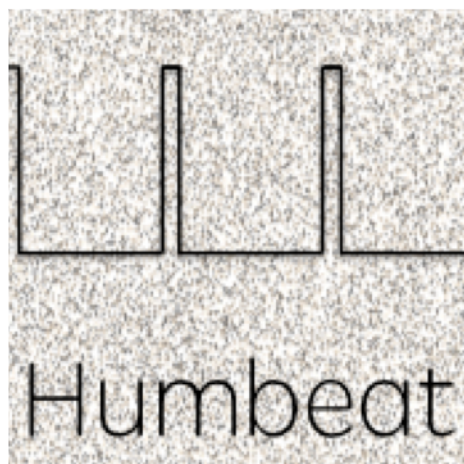


Renewable variability and uncertainty in the UK electricity market

Humbeat uses key UK electricity market operational data to analyse the variability and uncertainty associated with today's renewable generation, and discusses how this will help define the requirements for future asset operability.



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Variability and uncertainty go hand-in-hand with renewable generation

Recently, many energy digests have announced large advances in RES capacity. For example, the UK Government's *DUKES*, and *Energy Trends* publications, show that renewable power output in the UK has roughly doubled since 2013, and now represents over 15% of power supplied in the year-to-date, 2016. A key consideration for our dependence on low-carbon electricity generation, is how we integrate these intermittent, renewable electricity supplies ("RES") efficiently and effectively into whole electricity systems.

It is expected that RES capacity will continue to grow, thus conferring an ever-greater importance to solving the challenge of effective integration. The two characteristics making integration a challenge, are the variability and uncertainty in RES output. So first we must define variability and uncertainty.

We'll associate variability with forecasts. Today will be cloudy. Tomorrow: sunny. The weekend will be windy; next week: still. *Variability* may be characterised by the range within which a forecast may be expect to lie. Variability requires different operational plans to be put in place to operate electricity systems from one day to the next. We'll associate *uncertainty*, on the other hand, with inaccuracies in generation forecasts over near-term timescales, requiring reactive mitigations, rather than forward planning.

So we'll look at just how variable and uncertain RES output is currently in the UK. While the data we use is specific to the UK market, the observations made and the methods of analysis used, are highly likely to be applicable to other electricity markets.

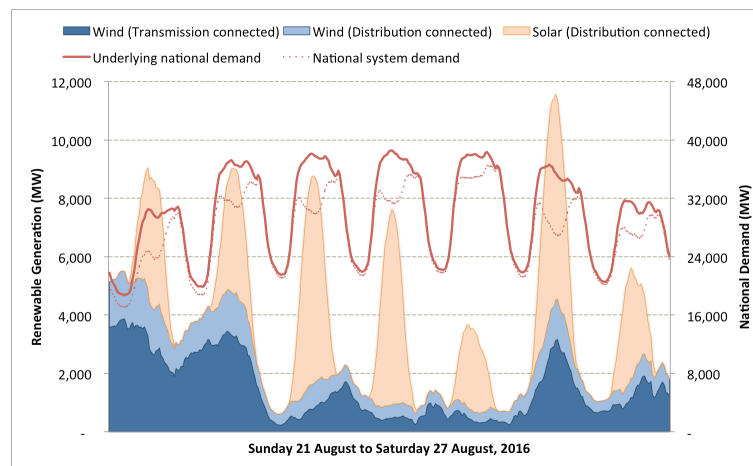
Phew! What a week

There is currently c. 24 GW of solar and wind capacity connected to the UK's electricity systems. One third of this is Transmission System connected wind generation: accurately metered, visible and responsive to System Operator instructions. The remainder is connected below the transmission network level, with twice as much capacity of solar as of wind.

All generation contributes to meeting demand, independent of where or how it is connected to the electricity system. Electricity system management however does vary according to where the generation arises – both in terms of geography, and connection level, as currently distribution-connected generation will tend to displace transmission-connected generation in a system-wide dispatch hierarchy. It therefore remains relevant to maintain a differentiation between transmission- and distribution-connected assets.

Taking a week in a view provides an example of just how variable day-to-day RES output can be. Chart 1 shows transmission-connected wind (dark blue area); distribution-connected wind (light blue area) and distribution-connected solar (orange area). These data are graphed against demand (solid red line) and transmission system demand (i.e. net of distributed generation: dotted red line).

Chart 1:

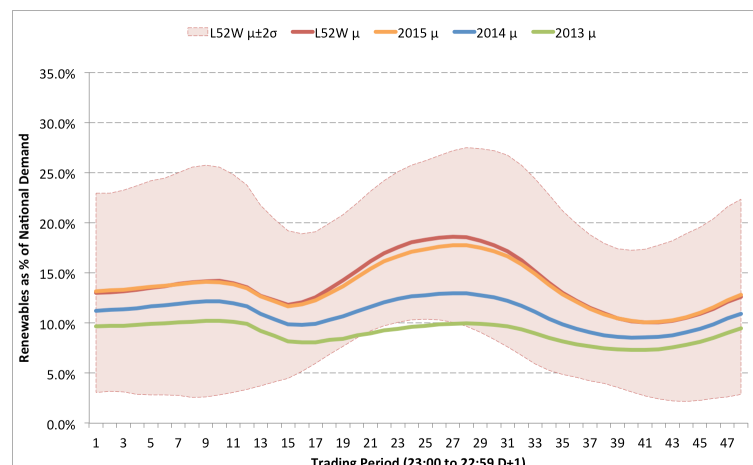


Strong wind generation over the course of a number of days may displace “baseload” power, but shorter occurrences of wind generation may make one day’s plan look very different to the next. Solar generation may dominate the middle of the day, but only if there is no cloud. Winters are likely to look very different to summers. Variability in RES output is a key driver for determining the running patterns of other electricity network users.

Knowing the unknown of the weather

The week shown above is not an “average” week. It is important to understand the *trends* of when, by how much, and how variable, RES generation occurs. Chart 2 shows the share of national demand met by RES from 2013 to end September 2016. Note the year-on-year increasing contribution of solar generation seen in the middle period of the day.

Chart 2:



Over the last 52 weeks, all but one day every three weeks lies within the shaded area of the graph. RES already regularly contribute above 25% of power demand at certain points of the day. The underlying data shows that both the contribution of RES towards meeting demand, and the variation in that contribution, are increasing. Inefficiencies in system operation may arise when variability within one class of generating asset is dominant within the system.

Further dissecting the data underpinning Chart 2 reveals that:

- RES share peaks early in winter mornings, but in the middle of summer afternoons;
- RES share during winter overnights remains high;
- Non-business-day demand is met by relatively more RES than business day demand (which is generally higher); and
- RES share is more variable over weekends and holiday days than over workdays.

Without effective integration measures, further increases in the RES share of demand may accentuate these and other observations, with possible implications on all other users of the grid system. For example, a highly variable RES output profile may distort market participant's revenue capture strategies, and disrupt both reserve and conventional plant operating schedules.

There's a storm coming ...

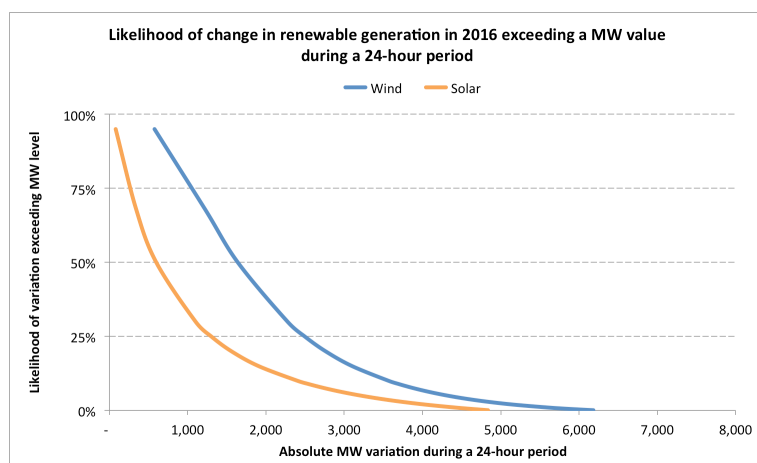
Variability can also be characterised by foreseeable changes in generation patterns over timescales of days or more: windy days may string together; we hope for weeks of cloudlessness back-to-back-to-back every summer! The reality is somewhat more disjointed than that.

Although seasonal trends are easily foreseeable, variability over shorter timescales leaves less opportunity for the planning of efficient and effective mitigations. Integration measures should be developed at a scale and capability, which will meet likely levels of near-term variability. So: what is a likely level?

Chart 3 shows the likelihood of a change in RES output over a 24-hour period being greater than the corresponding MW value. Note: we graph the change in peak generation for solar generation.

Wind is a larger contributor to output variability over day-to-day timescales. Statistically speaking, every other day we might see a spread of over 2 GW in wind output, and over c. 1 GW in peak solar output. These spreads may work with, or against, each other. Importantly though, both spreads have increased in proportion to RES capacity. We may therefore extrapolate average daily variations in output continue to increase with capacity. The market for integration measures will need to become more sophisticated, and grow, to manage RES variability without interrupting supply.

Chart 3:



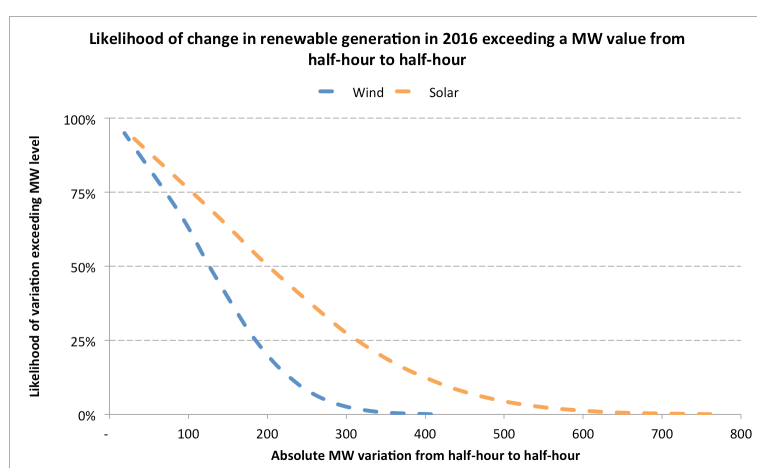
It is also important to understand what level of uncertainty is inherent RES output.

Managing the here and now

Chart 4 shows that solar generation more strongly influences response requirements over half-hour periods. This is related to the uncertainty of generation forecasts.

The underlying data also suggests that RES uncertainty increases in proportion to its installed capacity, but the immediate effects of uncertainty are currently an order of magnitude smaller than the longer-term effects of variability. Currently therefore uncertainty is not a significant issue in the UK. As RES capacities grow however, uncertainty will have an impact on the design and operation of mitigating measures, in particular the amount and type of reserve generation required by the System Operator and instructions to dispatchable assets.

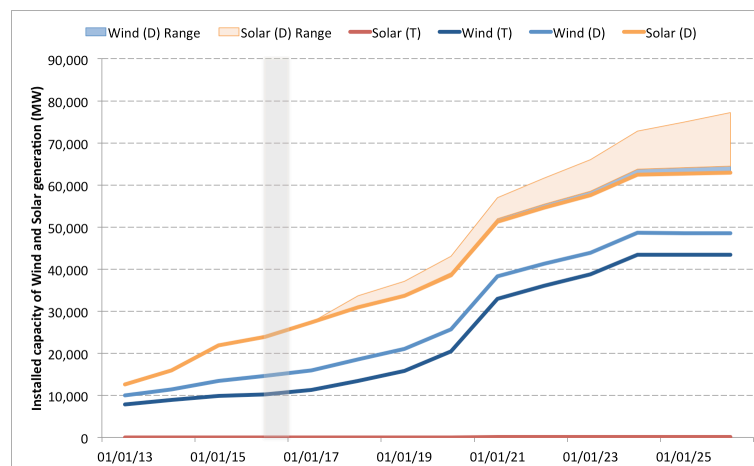
Chart 4:



Looking to the future

Capacities of wind and solar power have grown since 2013. They are expected to continue to grow through to 2026 as shown in Chart 5. The shaded areas represent the range covered by The National Grid Company's Future Energy Scenarios (2016). By sensibly extrapolating an analysis of today's variability and uncertainty, it will be possible to make a number of conclusions on the scale and nature of the future integration challenge.

Chart 5:



Crudely, in four years time, renewable capacity is expected to double. Variability and uncertainty as we have defined them may also double. We will require much more asset- and market- based integration, in the future than we see today. The growth in integration measures (such as storage, VPPs, interconnectors and consumer incentives) may need to outstrip that of RES capacity to catch up.

Understanding the facts about today's markets, and tracking how they evolve, will be important to ensure that future measures are designed to be capable of mitigating future expected levels of variability and uncertainty. In the longer term, their business cases and commercial operation may depend on it.