How Did British Generators' Output Patterns Respond to Demand, Costs and Renewable Generation?

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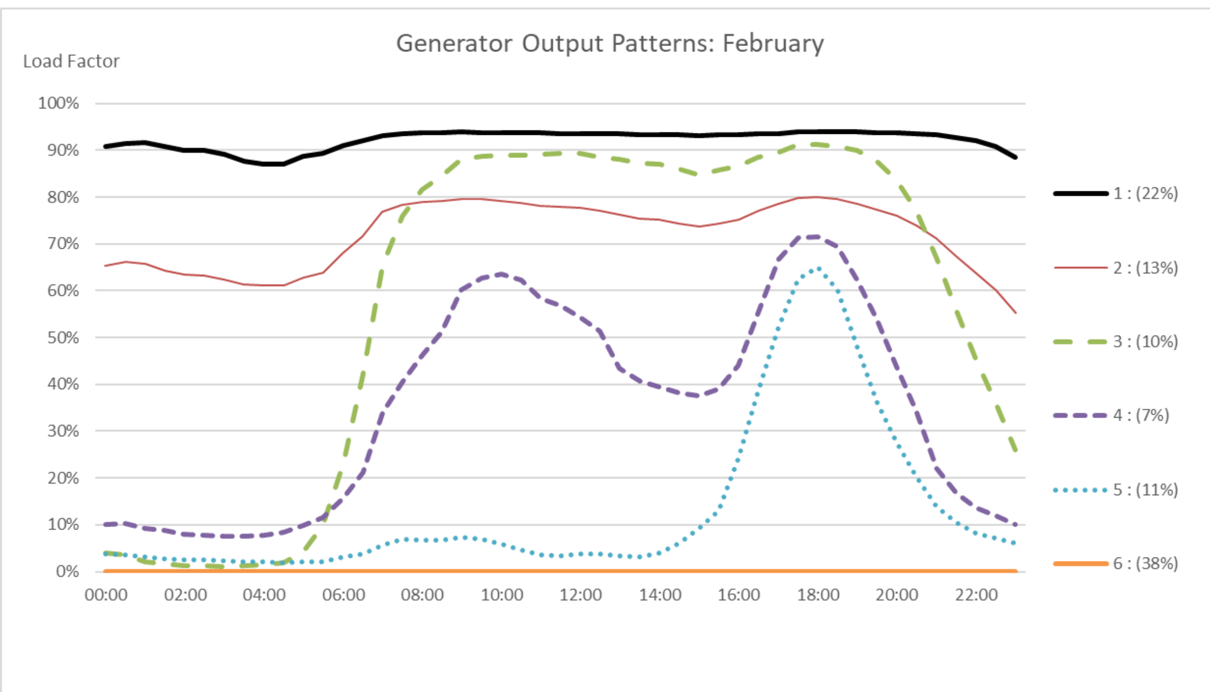
Overview

Power stations mostly follow predictable operating patterns. Some run on baseload, with a continuously high output level. Others "two-shift", turning off overnight and returning to service as demand ramps up in the early morning. Peakers may only generate for the few hours a day of highest demand. Other stations follow a more complex pattern, however, reducing output as demand falls overnight in order to avoid the thermal stress of shutting down and starting up again.

Which stations follow which patterns will depend on the level and shape of the demand for electricity, the stations' relative costs and their technical characteristics. Lower-cost plants (in terms of variable cost) will usually generate more; inflexible plants may be forced to follow a baseload pattern or to switch off altogether. This paper will explore these operating patterns and the factors that drove them for the stations in the British electricity market.

Methods

We have half-hourly output data for every significant generator in the British electricity market from 2009 to 2019. We can use k-means clustering (e.g. Guo *et al.,* 2020) to group the stations according to their pattern of output over the 48 half-hours of each day. The figure below gives an example for February: each line shows the mean output for a group of stations.

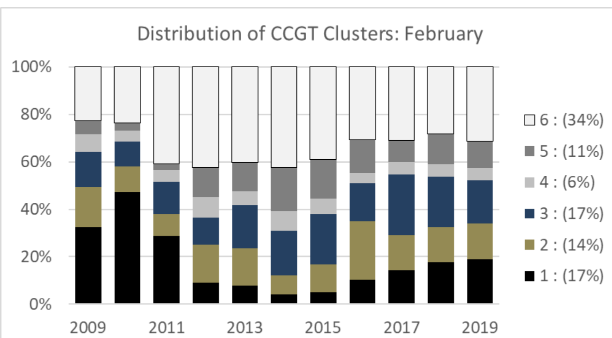


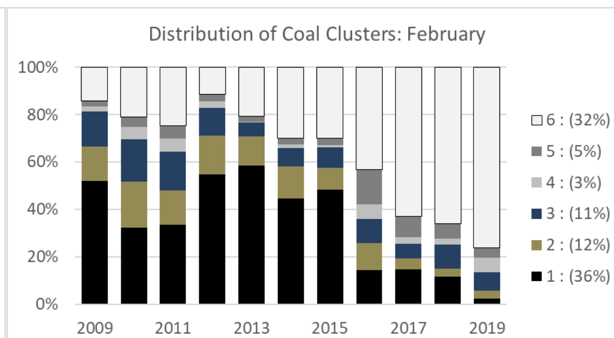
The stations in cluster 1 (which make up 22% of our sample) are running base-load, close to full output throughout the day. Those in cluster 2 also run continuously, but reduce output as load falls overnight. Cluster 3, however, turn off overnight and incur start-up costs (fuel and mechanical wear and tear). Cluster 4 groups stations that turn on for the morning peak in demand, turn down in the middle of the day and then increase output for the evening peak, while cluster 5 contains those which only run for the evening peak. Finally, cluster 6 contains the many stations which did not run at all on a given day.

We treat each month separately because the daily shape of demand varies with the time of year. We group weekday outputs for (e.g.) February in every year of our data into a single sample and obtain a single set of clusters that describe the generators' output patterns at that time of year throughout the decade of changing fuel and carbon prices and growing renewable output. We will then estimate the relationship between each station's output patterns and variables such as fuel and carbon prices, available capacity, electricity demand and the level of renewable output. While we will explore other approaches, we will start with a multinomial probit model for the probability that each generating unit belongs in a given cluster. The probability of a station belonging to a high-output cluster (e.g. 1 or 2 in the diagram above) will fall as the relative level of its fuel and carbon costs rises. For a low-output cluster, the probability will increase as the station's relative costs increase. As wind and solar output increases, we expect to see a falling proportion of stations in the higher-output clusters, with more of them turning on and off each day to meet the increasingly volatile pattern of residual demand.

Results

This is work in progress. We have obtained sets of clusters for the months we intend to study, and have the data we need for demand, renewable output and fuel and carbon prices. We have not yet started with our regression analysis but are confident that we will have results to report in good time for the conference. The diagrams below show that CCGT plants were least likely to follow the baseload output pattern (Cluster 1) during 2012-15, when gas was expensive relative to coal. From mid-2015 on, a higher cost of carbon made coal generation more expensive than gas, while the share of wind and solar output rose rapidly. In this period, coal units are very unlikely to run on baseload and increasingly likely to spend an entire day offline (Cluster 6). While the patterns in these charts (which reappear in other months) are intuitive, our regression analysis will estimate the strength of these relationships.





Conclusions

Generators' output patterns are changing as renewable electricity becomes an ever-more important part of the European energy mix. Understanding these changes will contribute to the literature on the carbon savings due to renewable generation (e.g. Kaffine *et al.,* 2013; Chyong *et al.,* 2020). The marginal cost of electricity, a key determinant of its price, also depends on the way in which generators are operating; when many generators are part-loaded, marginal cost is likely to be low. Insights here could help in modelling the future course of electricity prices.

References

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