VALUE OF SOLAR PHOTOVOLTAICS IN SINGAPORE: CALCULATING THE MERIT ORDER EFFECT

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Overview

With no indigenous resources of fossil fuels, and a poor wind resource, solar photovoltaics (PV) is the main focus for additions to Singapore's domestic energy supply. However, a high penetration of PV in the power sector would result in a number of costs and benefits that need to be quantified in order to ensure prudent government policies for "supporting" the widespread adoption of PV in Singapore. The concept of the "value" of solar stems from the limitations of using the levelised cost of electricity (LCOE) as a metric for evaluating the unit cost of alternative power generation technologies that include variable (i.e. intermittent) renewable energy (VRE) supplies. This paper addresses this issue by deriving an overall economic value that solar PV brings to society. In the context of the Singapore power system, the determination of these costs and benefits involve the savings due to the merit order effect and net avoidance of CO2 emissions. Costs due to additional frequency control services to deal with PV uncertainty and variability are considered in a separate paper.

Methods

Calculating the merit order effect:

- Average solar radiation data from five locations across Singapore was converted into PV output for 600 MW, 1GW, and 2GW capacities on a half-hourly scale between 7 am and 7 pm.
- Daily bidding data from the National Electricity Market of Singapore (NEMS) were stacked from low to high, and the marginal clearing price was estimated by comparing the stacked value with half-hourly demand data, thus deriving the corresponding price of the last offer dispatched.
- PV output put was then subtracted from demand and a new clearing price was determined from the "new" last offer dispatched.
- Price-quantity pairs with and without PV were determined for each trading period, and the merit order effect was calculated as the difference in total revenue between the two measures.

This process was repeated for an entire year (2014), from 07:00 to 19:00, for every 30-minute trading interval.

The process was repeated using simulated solar irradiation data for Singapore provided by Meteonorm.

Results

In aggregate, over the full year, the results were very similar for both the "real" and "simulated" data sets, although there were significant differences for individual trading periods.

The Singapore power sector is dominated, almost exclusively, by gas-turbine technologies. Thus the domestic savings in CO2 emissions from adoption of PV can be calculated by evaluating the corresponding reduction in gas combusted by the power sector.

	National Environment Agency data			Meteonorm data		
	600 MW	1 GW	2 GW	600 MW	1 GW	2 GW
Merit order effect	$468.7 million	$606.8 million	$932.6 million	$450.7 million	$593.8 million	$959.0 million
Tonnes CO_2 avoided	0.595 million	0.992 million	1.985 million	0.594 million	0.990 million	1.981 million

Conclusions

As would be expected the merit order effect becomes more pronounced as the share of PV in the system increases, and at 2 GW PV penetration the wholesale market clearing price drops to zero in some instances. Such a result is not unexpected, as it has been assumed that the existing fossil fuel generators do not adapt their bidding behaviour in order to secure dispatch. In particular, during times of low PV output, they may become more aggressive in their bidding behaviour particularly if excess fossil fuel capacity is mothballed as PV capacity increases.