Flexible Forward Contracts for Renewable Energy Generators

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Wind power is variable: Can we have insurance against this variability in wind power?

How can the variability of wind power be insured against the uncertainty of real time price?

- Variability in renewable resource output
- Prevents renewable resources to engage in day ahead and forward contracts
- Generation owners exposed to real time price fluctuations

Day ahead contract would impose firm power delivery obligation for the windfarm

![Real time price fluctuations](chart.png)
Flexible Forward Contract: If purchasers are flexible with their load demand they get to pay a lower price...

- Utilizing the time and demand flexibility of flexible loads
- Forward contract with built-in flexibility
- Permit deviation from committed amount
- Constraints on total served energy
- Lower than day ahead market price for flexible load
- Agreed deductible when partial failure to fulfill the obligation

A flexible forward contract between renewable resource and flexible load

Purchaser’s price
Wind plant risk

Aggregator to combine flexible load

- Windfarm’s variability
- Aggregator's flexibility
- Flexible forward contract
- Reduced price
Allowing flexibility with some bounds.

\[
\max_{\rho_t^f} E \left\{ \sum_{t=1}^{T} \rho_t^f \times \pi_t^f + (\text{Wind}_t^f - \rho_t^f) \times \text{Real}_t^f \right\} 
\]

Accurate forecast of real time price will benefit the supplier to improve its payoff.
Don’t take advantage of this leniency!

\[ \pi_t^f \leq D ay_t \]

Make me a better offer

I don’t need more than my ability to consume

Don’t oversupply at different intervals

Fulfil some energy obligation at different intervals
Are there any value propositions for each stakeholder?

<table>
<thead>
<tr>
<th>Renewable Resource</th>
<th>Aggregator / Flexible Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Insurance against uncertain wind and real time price spikes</td>
<td>✓ Lower price than day ahead market price</td>
</tr>
<tr>
<td>✓ Flexibility to deviate from committed uncertain generation / forecast</td>
<td>✓ Fulfilling energy demand from renewable resources</td>
</tr>
<tr>
<td>✓ Can make a more aggressive forward bid</td>
<td>✓ Improve RPS requirements if any</td>
</tr>
<tr>
<td>✓ Opportunity to take advantage of real time price spikes</td>
<td>✓ Loss of certainty about available power</td>
</tr>
</tbody>
</table>

**System operator**

✓ Reduces requirement to schedule demand response or call reserves due to renewable resource unavailability (self scheduling)
✓ Potential improvement in system renewable generation portfolio
✓ Lower cycling of conventional generators
✓ No significant changes required in most present market rules and regulations
Contract setup

- Base case of 500 cars
- Arrival (5:00 PM to 9:00 PM)
- Some require 75% charge
- Some require 50% charge
- Try different number of cars (400 – 600)
- Different levels of flexibility (0 to 9 hours)
- An average power supply rate of 10 kW
- An average battery capacity of 50 kW-hr

Assume transaction price is equal to day ahead price for comparison purpose.
Analyzing the available flexibility

Each car charges to 100% of its capacity in 5 hours at maximum power supply rate.
How much impact can price forecasting have?

Using accurate forecast allows the supplier to dispatch optimally between the forward contract and spot market.

Revenue in $/MW of capacity when forecast of real time price is used.

Revenue in $/MW of capacity when actual value of real time price is used.
More flexibility might permit the supplier to serve a higher load.

With no flexibility, revenues might decrease as load increases (may have to fill the void in spot market).

Revenue in $/MW of capacity when forecast of real time price is used.

Revenue in $/MW of capacity when actual value of real time price is used.
Art of the deal: An example of negotiated transaction price

- 3 hours of flexibility in the load
- Flexible load will not agree to pay more than the minimum it would pay under day ahead market price
- Contract price for the three highest priced hour were set lower than the three lowest priced hour in day ahead market

<table>
<thead>
<tr>
<th>Time (Hrs)</th>
<th>Power supplied (MW)</th>
<th>Day-ahead price ($/MWhr)</th>
<th>Transaction price ($/MWhr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17:00</td>
<td>0</td>
<td>52.6</td>
<td>16.0</td>
</tr>
<tr>
<td>18:00</td>
<td>0</td>
<td>48.4</td>
<td>16.0</td>
</tr>
<tr>
<td>19:00</td>
<td>0</td>
<td>41.3</td>
<td>16.0</td>
</tr>
<tr>
<td>20:00</td>
<td>1</td>
<td>36.9</td>
<td>36.4</td>
</tr>
<tr>
<td>21:00</td>
<td>2</td>
<td>29.3</td>
<td>28.8</td>
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<tr>
<td>22:00</td>
<td>3</td>
<td>28.5</td>
<td>28.0</td>
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<tr>
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<td>27.0</td>
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<tr>
<td>01:00</td>
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<td>19.6</td>
</tr>
<tr>
<td>02:00</td>
<td>3</td>
<td>16.6</td>
<td>16.1</td>
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<tr>
<td>03:00</td>
<td>2</td>
<td>16.3</td>
<td>15.8</td>
</tr>
<tr>
<td>04:00</td>
<td>1</td>
<td>17.1</td>
<td>16.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Revenues and Payments</th>
<th>Amount ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payments by load in day-ahead market</td>
<td>595.64</td>
</tr>
<tr>
<td>Payments by load in proposed contract</td>
<td>583.14</td>
</tr>
<tr>
<td>Windfarm revenue if it sells in real time</td>
<td>282.98</td>
</tr>
<tr>
<td>Windfarm revenue in proposed contract</td>
<td>464.33</td>
</tr>
</tbody>
</table>

Renewable resource makes more
Load pays a lower price
Conclusion and future possibilities

✓ Proposing a flexible forward contract for renewable resources with variable power to participate in forward markets

✓ Despite lower transaction price, renewable resources can take advantage of real time price spikes by utilizing the flexibility in the contract

✓ Flexible loads end up paying lower amounts than they would under the day ahead market prices

✓ Higher the flexibility, higher the benefit to the renewable resource

? How to efficiently aggregate multiple flexible loads while keeping the actual flexibility and demand requirement?

? How to set the transaction price?

? Is there an optimal combination of flexible contract and fixed contract that windfarm can undertake?
Thank You

Questions