Agent-based analysis of dynamic access ranges to the distribution network

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Outline

Introduction

Coordination problems with flexible accesses

Dynamic access ranges

DSIMA: an interaction model simulator

Results
Congestion in distribution networks

- Distributed generation, such as wind farms, causes congestions in distribution networks.
- The solution is to upgrade the network or to use the flexibility within the network:
  1. curtail the production,
  2. shift the consumption.
- The Distribution System Operator (DSO) does not own the flexible assets.
- Using flexibility impacts financially the flexible assets owners.

A framework, called an interaction model, is needed to define how flexibility should be exchanged in distribution networks.
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Access agreement

The interaction models are based on access contracts.

- The grid user requests an access to a given bus.
- The DSO grants a full access range and a flexible access range.

The filled areas represents the restrictions of the DSO.
Coordination problem

• Assume that the flow exceeds the capacity of line 3 by 1MW.
• To solve this issue, the DSO curtails a wind mill by 1MW.
• Simultaneously, the TSO asks a storage unit to inject 0.4MW.
• These activations lead to a remaining congestion of 0.4MW.
Coordination problem: two causes

1. The storage unit is in its safe range:
   - Full access range

   The DSO should anticipate the deviation of the storage unit.

2. The storage unit is out of its safe range:
   - Flexible access range

   The production of the storage unit should be limited so that the actions of the DSO cannot be counterbalanced.
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Dynamic access ranges: definition

The dynamic (full) access ranges change each quarter based on the distribution network limitations computed by the DSO.

The procedure to obtain the dynamic ranges is:

1. Grid users provide baseline proposals.
2. The DSO computes the dynamic ranges and communicates them to grid users.
3. Grid users submit new baselines within the dynamic range.
Dynamic ranges: back to our coordination problem

<table>
<thead>
<tr>
<th></th>
<th>Safe access range</th>
<th>Baseline proposal</th>
<th>Dynamic access range</th>
<th>Previous Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind mill</td>
<td>[0, 5]</td>
<td>7</td>
<td>[0, 6]</td>
<td>6</td>
</tr>
<tr>
<td>Storage unit</td>
<td>[−1, 1]</td>
<td>0</td>
<td>[−1, 0]</td>
<td>0.4</td>
</tr>
</tbody>
</table>

The TSO cannot ask anymore the storage unit to increase its production and the DSO prevents the congestion of line 3.
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DSIMA: purpose & implementation

• To study short-term flexibility exchanges in an operational planning phase.

• The actors simulated are the DSO, the TSO, producers and retailers, and may fulfill more than one role.

• The testbed is available as an open source code at the address http://www.montefiore.ulg.ac.be/~dsima/.
Decision stages

- Global baseline
- Local baselines
- Flexibility needs
- Flexibility offers
- Flexibility contracts
- Flexibility activation requests
- Flexibility platform

Producers & Retailers

TSO

Settlement

DSO
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Case study

- Results are given for a 75 bus test system.
- Results show that the DSO should consider a security margin of at least 30% to avoid shedding issues.
- Welfare of the dynamic model is compared to a restrictive model where there is no flexible ranges and only safe access ranges.
- A practical choice for this application would be to consider security margins of 40%. Welfare would be increased with respect to the restricted model by 47% and the total production by 55%.
Evolution of the yearly shed production with the relative maximal deviation parameter considered by the DSO

![Graph showing the relationship between security margin and total energy shed. The graph plots the total energy shed (MWh) against the security margin (%). As the security margin increases, the total energy shed decreases significantly.]
Welfare and total production increase as a function of the relative maximal deviation parameter with respect to a conservative interaction model.
Conclusion

Summary

• Study of flexibility services exchanges within a distribution system.
• Proposal of an interaction model with dynamic access bounds.
• These bounds are computed using baseline proposals.
• Compared to restrictive accesses, this model safely increases by 55% the distributed generation and the welfare by 42.5%.

Ongoing & future work

• Propose an interaction model solving the coordination problem DSO-TSO. ✓
• Refine the modeling level: AC power flow. ✓
• Study the entry or exit of new players or production units.
• Compare to network reinforcement decisions.
More information

Open-source testbed

http://www.montefiore.ulg.ac.be/~dsima

The Gredor project

http://www.gredor.be

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Appendix - Baseline proposal: motivation

A baseline proposal incentivize a grid user to produce in its dynamic range established on a definitive baseline.

Example: producer

<table>
<thead>
<tr>
<th>Flexible range</th>
<th>Baseline</th>
<th>Dynamic range</th>
</tr>
</thead>
<tbody>
<tr>
<td>[5, 8]MW</td>
<td>8MW</td>
<td>[0, 6]MW</td>
</tr>
</tbody>
</table>

Choices of the producer

1. Paying an imbalance of 2MW to the TSO.
2. Paying a penalty to the DSO for the 2MW of violation.
3. Selling a downward modulation of 1MW, produce 7MW and pay a 1MW penalty to the DSO.
Appendix - One day of a producer selling flexibility services

Assume a specific interaction model and one hour: 8 to 9am. A producer performs the following actions:

1. Send its baseline to the TSO at the high-voltage level.
   *I will produce 15MWh in distribution network 42 between 8 and 9am.*

2. Send its baseline to the DSO at the medium-voltage level.
   *I will produce 5MWh in bus 20 between 8 and 9am.*

3. Obtain flexibility needs of the flexibility services users.
   *The DSO needs 3MWh downward in bus 20 between 8 and 9am.*

4. Propose flexibility offers.
   *I can curtail my production by 2MWh in bus 20 between 8 and 9am.*

5. Receive activation requests for the contracted services.
   *Curtail production by 1MWh in bus 20 between 8 and 9am.*

6. Decide the final realizations.
   *Produce 4MWh or 5MWh in bus 20 between 8 and 9am.*