Model Predictive Dispatch in Electric Energy Systems with Intermittent Resources

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Outline

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• Problem Formulation
• Proposed Algorithm for Economic Dispatch with Intermittent Resources
• Numerical Examples
• Summary and Future Work
Motivation

• Increasing presence of renewable energy resources which are
  – Environmentally attractive 😊
  – Intermittent 😞

• Reliability and efficiency concerns for renewable resources due to intermittency

• Three major questions:
  Better Prediction of Intermittent Resources?
  More efficient utilization of intermittent resources
  More reliable operation of intermittent resources

This paper
Problem Statement

• Economic Dispatch (ED): given a mixture of energy resources, how to determine the output of individual energy resources so that (1) power supply always balances demand (2) total generation cost is minimized?

\[ \text{Solve: } \min_{P_{G_i}(k)} \sum_{k=1}^{K} \sum_{i} C_i(P_{G_i}(k)), \quad i \in G \]

\[ s.t. \sum_i P_{G_i}(k) = \hat{L}(k), \quad i \in G, \quad k = 1, 2, \ldots, K; \]

\[ P_{G_i}^{\text{min}} \leq P_{G_i}(k) \leq P_{G_i}^{\text{max}}, \quad k = 1, 2, \ldots, K; \]

\[ |P_{G_i}(k+1) - P_{G_i}(k)| \leq R_i, \quad i \in G; \]
Conventional Approach to ED

- Supply the expected load with whatever produced by intermittent resources combined with other traditional power plants.

Economic Dispatch (ED): Choose output levels from conventional power plants to meet the “net load” at minimum cost.
Conventional Approach to ED

• Pros: 🧡
  – easy to implement
  – computes a reasonably good selection of generator outputs in “old days” when renewable resources are almost negligible in power systems

• Cons: 😞
  – No flexible utilization of intermittent resources
  – High cost of keeping expensive fast-start units on in order to balance the high volatility of intermittent resources
Proposed Approach: Concept

• Actively control the output of available intermittent resources to follow the trend of time-varying loads.

• By doing so, the need for expensive fast-start fossil fuel units is reduced. Part of the load following is done via intermittent renewable generation.

• The technique for implementing this approach is called model predictive control (MPC).
Model Predictive Control: Concept

- MPC is receding-horizon optimization based control.
- At each step, a finite-horizon optimal control problem is solved but only one step is implemented.
- MPC has many successful real-world applications.
Proposed Approach: Algorithm

- Predictive model of load and intermittent resources are necessary.
- Optimization objective: minimize the total generation cost.
- Horizon: 24 hours, with each step of 5 minutes.
Numerical Experiment

TABLE I
GENERATOR PARAMETERS OF THE 12-BUS SYSTEM

<table>
<thead>
<tr>
<th>Gen ID</th>
<th>Type</th>
<th>Capacity</th>
<th>Marginal Cost</th>
<th>Ramp Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Natural Gas</td>
<td>5000MW</td>
<td>1000$/MWh</td>
<td>100MW/5 min</td>
</tr>
<tr>
<td>2</td>
<td>Coal</td>
<td>9000MW</td>
<td>500$/MWh</td>
<td>1000MW/hour</td>
</tr>
<tr>
<td>3</td>
<td>Wind</td>
<td>3500MW</td>
<td>0$/MWh</td>
<td>150MW/5 min</td>
</tr>
<tr>
<td>4</td>
<td>Photovoltaic</td>
<td>1500MW</td>
<td>0$/MWh</td>
<td>100MW/5 min</td>
</tr>
<tr>
<td>5</td>
<td>Coal</td>
<td>8000MW</td>
<td>300$/MWh</td>
<td>800MW/hour</td>
</tr>
</tbody>
</table>

Compare the outcome of ED from both the conventional and proposed approaches.
Numerical Experiment

<table>
<thead>
<tr>
<th>Conventional cost over 1 year *</th>
<th>Proposed cost over the year</th>
<th>Difference</th>
<th>Relative Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>$129.74 Million</td>
<td>$119.62 Million</td>
<td>$10.12 Million</td>
<td>7.8%</td>
</tr>
</tbody>
</table>

Summary

• Look-ahead model predictive dispatch of future energy system is proposed.
• Combined with good short-term prediction of intermittent resource outputs, the proposed method can lower the total generation cost.
• The proposed method provides a benchmark towards optimal percentage of wind generation for grid and for storage.
• More intelligent utilization of intermittent resources can actively follow the load variation trend, thus lower the total generation cost.
Future Work

• Scale issue: how to make this algorithm fast enough in large-scale system?
• Multi-objective problem: how to generalize the algorithm to study the tradeoff between environmental and economic costs?
• More realistic model: how to include more realistic factors (e.g. transmission constraints) into the predictive dispatch model?
Acknowledgement
Thank you!

Questions are welcome to be sent to {lx,milic}@ece.cmu.edu or visit us at www.ece.cmu.edu/~eessg