Carnegie Mellon

Model Predictive Dispatch in Electric Energy Systems with Intermittent Resources

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Electrical & Computer ENGINEERING

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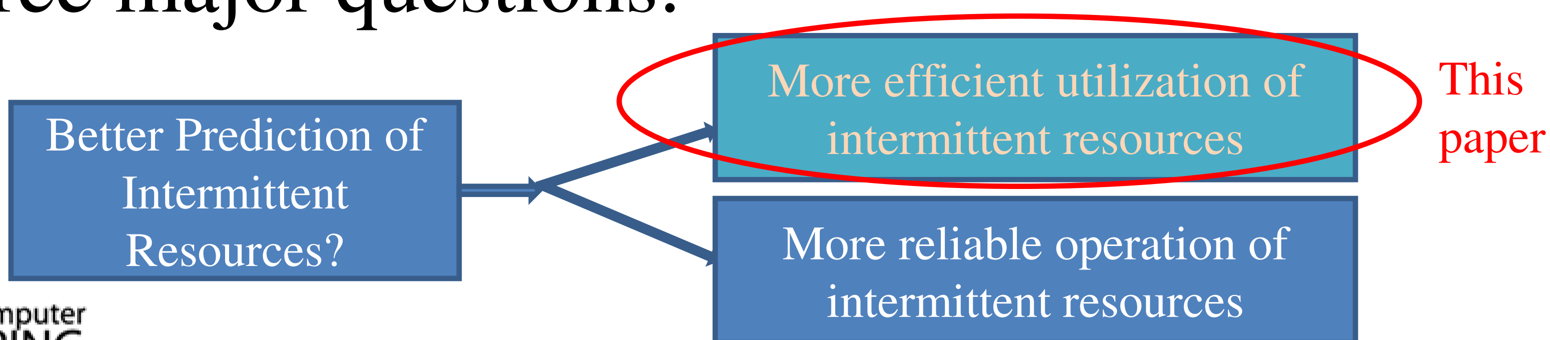
Outline

- Motivation
- 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:



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?

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

Total Gen Cost

$$s.t. \sum_{i} P_{G_i(k)} = \hat{L}(k), i \in G, k = 1, 2, \cdots, K;$$

Supply=E(Demand)

$$P_{G_i}^{\min} \le P_{G_i}(k) \le P_{G_i}^{\max}, k = 1, 2, \cdots, K;$$

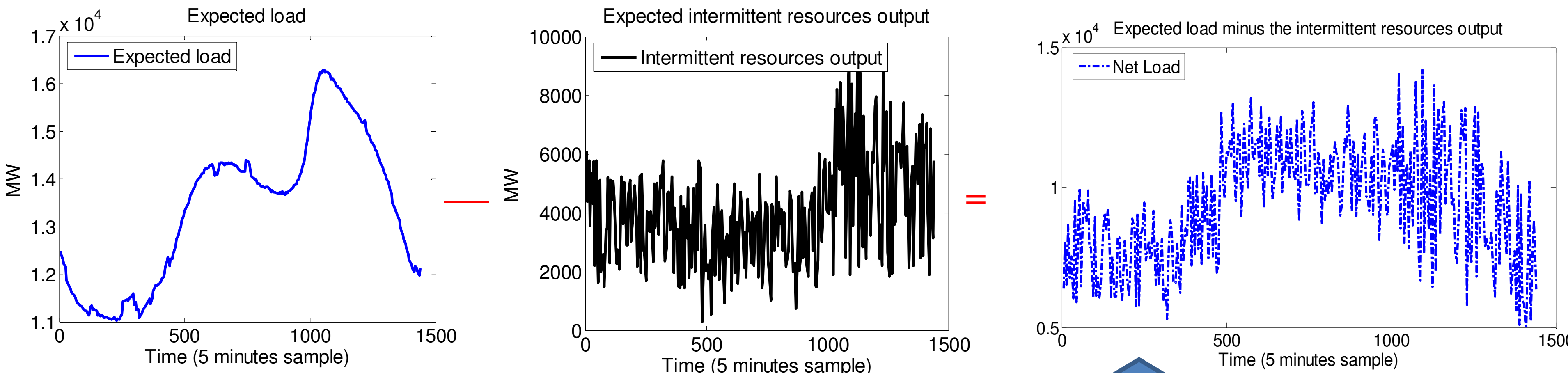
Gen Constraints

$$|P_{G_i}(k+1) - P_{G_i}(k)| \le R_i, i \in G;$$

Ramp rate constraints

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.

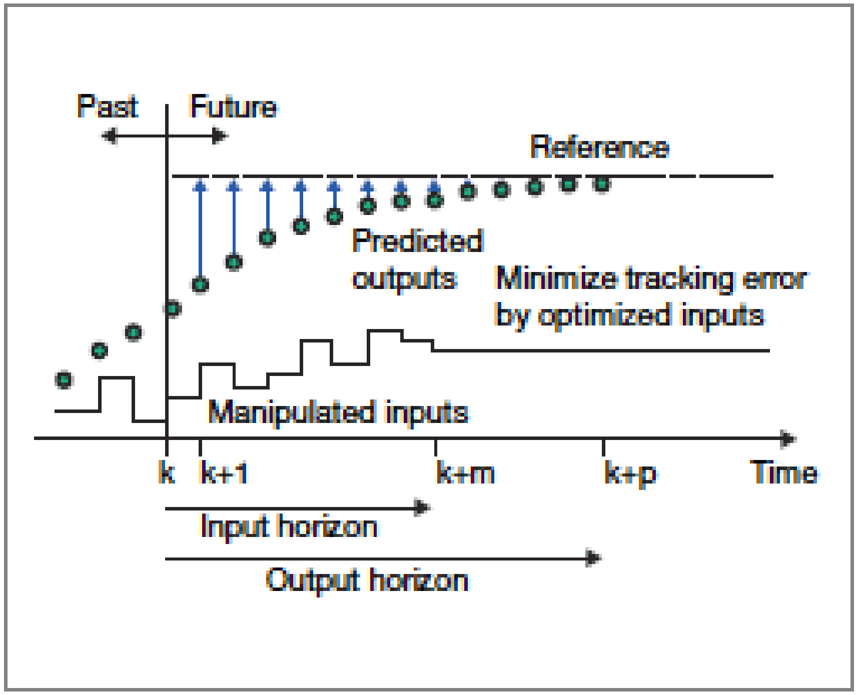
Conventional Approach to ED

- 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).

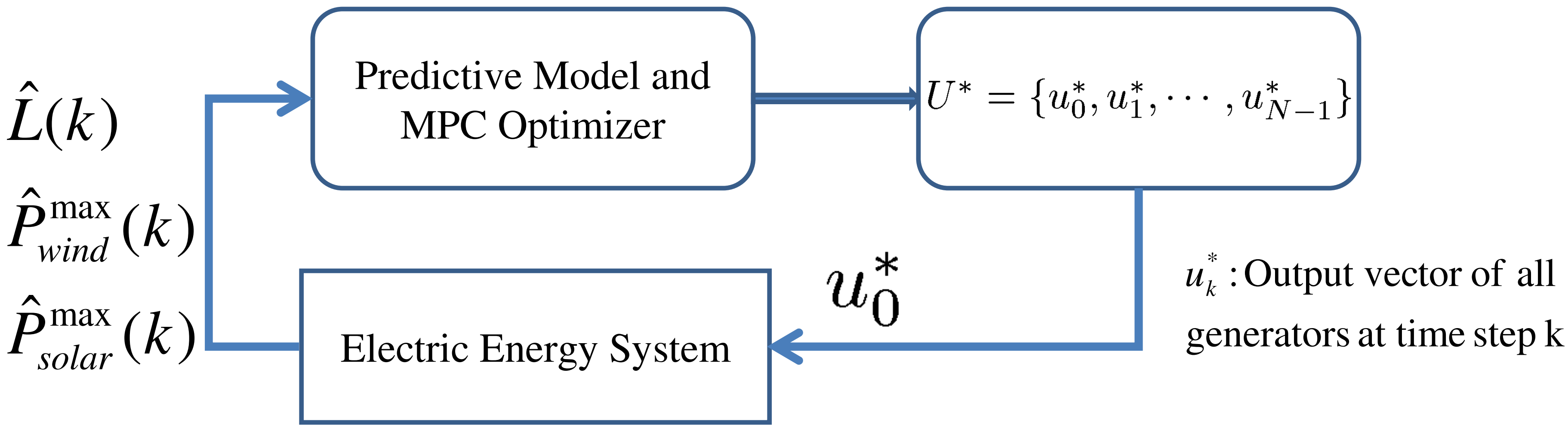
Model Predictive Control: Concept



www.jfe-rd.co.jp/en/seigyo/img/figure04.gif

- 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

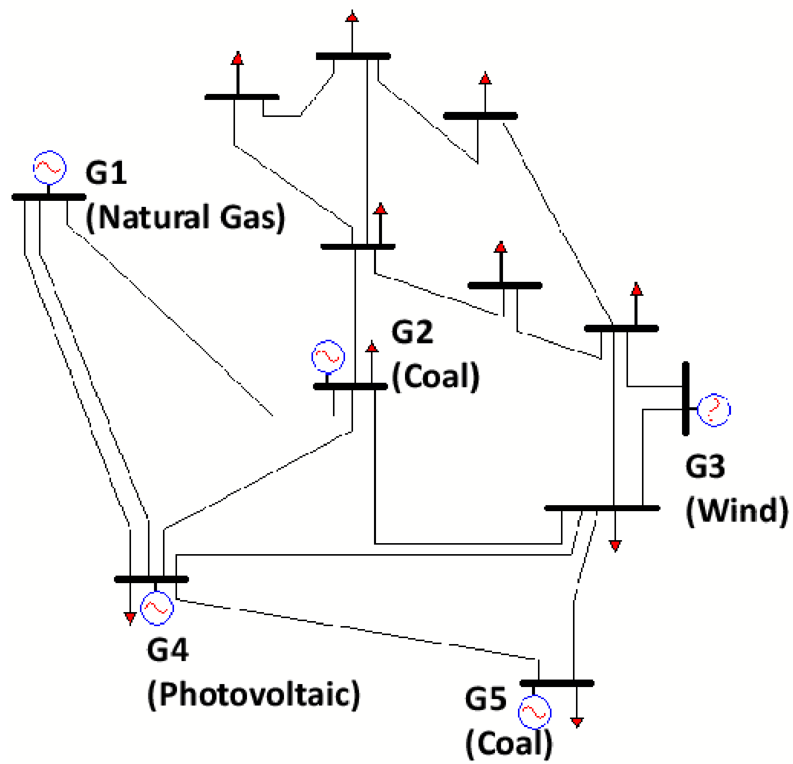
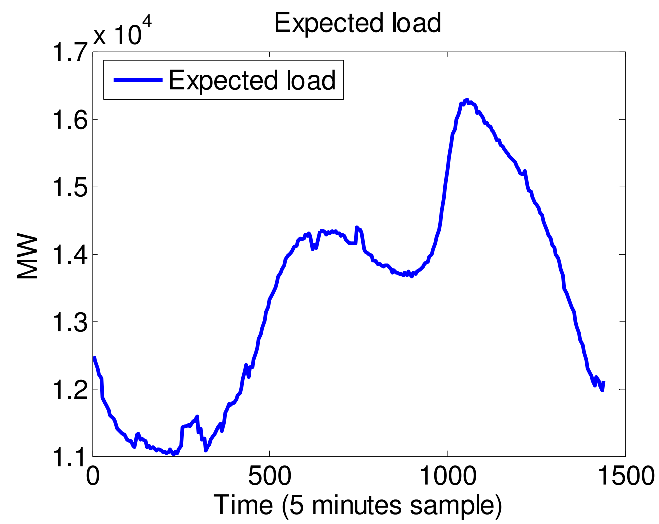


TABLE I
GENERATOR PARAMETERS OF THE 12-BUS SYSTEM

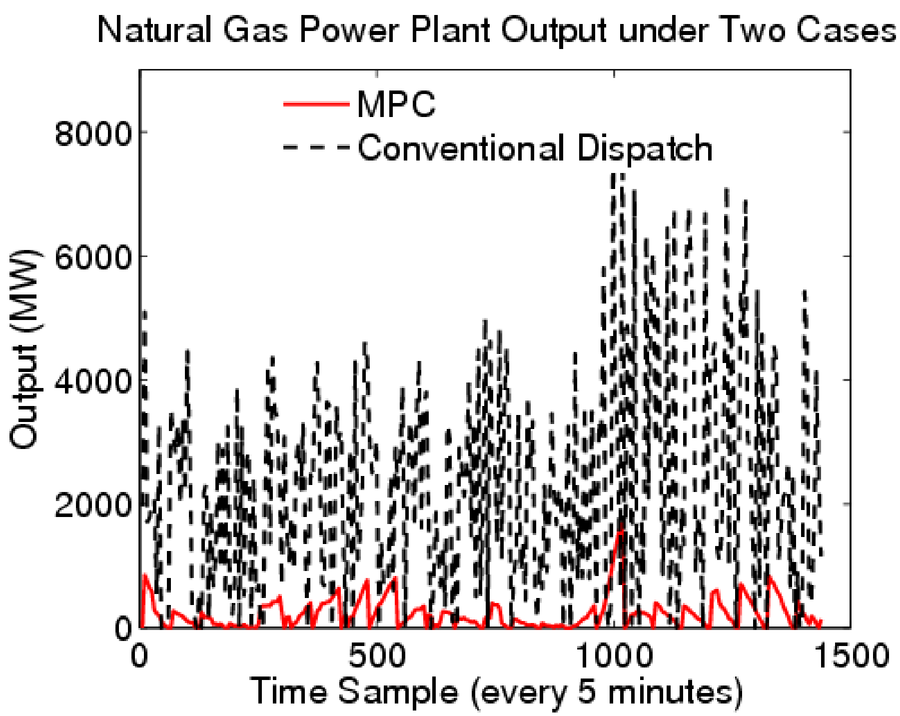
Gen ID	Type	Capacity	Marginal Cost	Ramp Rate
1	Natural Gas	5000MW	1000$/MWh	100MW/5 min
2	Coal	9000MW	500$/MWh	1000MW/hour
3	Wind	3500MW	0$/MWh	150MW/5 min
4	Photovoltaic	1500MW	0$/MWh	100MW/5 min
5	Coal	8000MW	300$/MWh	800MW/hour

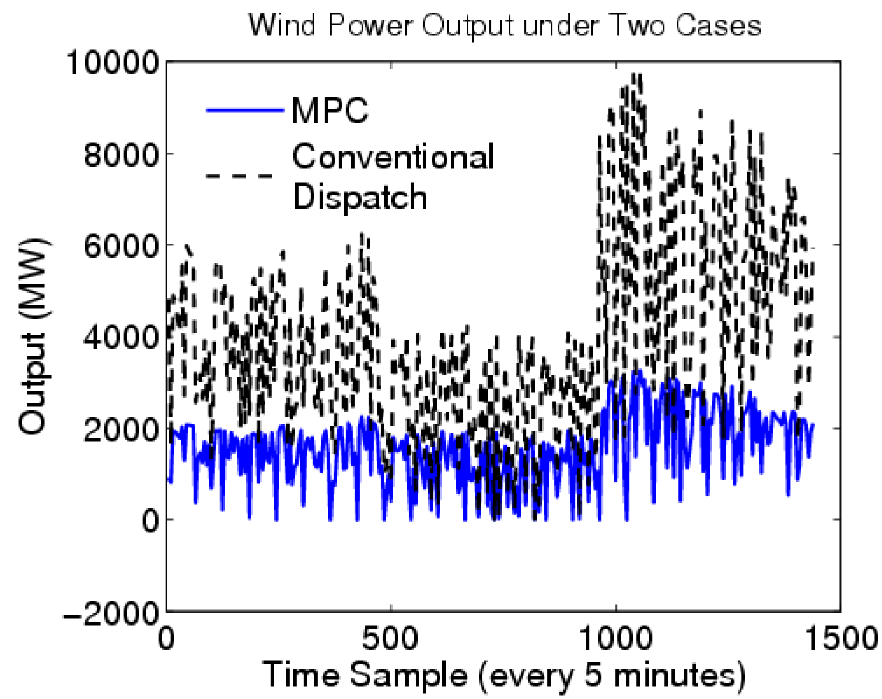


Compare the outcome of ED from both the conventional and proposed approaches.

Numerical Experiment

Conventional cost over 1 year *	Proposed cost over the year	Difference	Relative Saving
$ 129.74 Million	$ 119.62 Million	$ 10.12 Million	7.8%





*: load data from New York Independent System Operator, available online at http://www.nyiso.com/public/market_data/load_data.jsp

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

National Science Foundation
WHERE DISCOVERIES BEGIN

Thank you!

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

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