Environmentally Constrained Economic Dispatch Problem— A Unified Model

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Outline

- Introduction
- Proposed Methodology
- Case Study and Results
- Concluding Remarks

Introduction

Economic Dispatch ?

Determines the generation dispatch

Minimum instantaneous operating cost

Generation= Load + Loss

used in real-time energy management → Kernel of Power System

Introduction

Emission Dispatch ?

Determines the generation dispatch

Minimum amount of Emission

Pollution ?

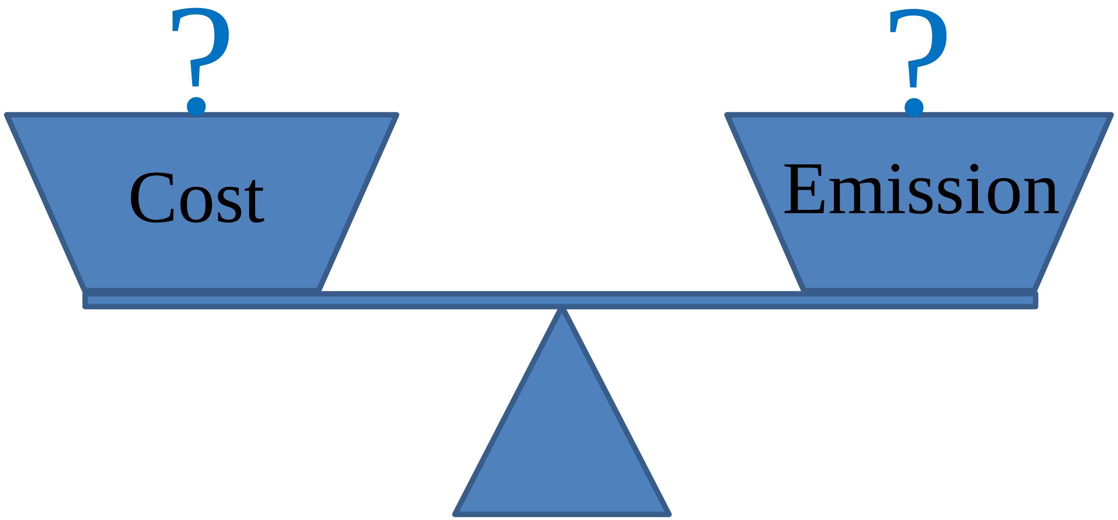
Concentration of emissions is reached to a pre-specified threshold

Introduction

Joint Dispatch ?

Simultaneous Consideration of Cost and Emission

Compromise between Cost and Emission



Mathematical Formulation

$$\min_{P_{i,t}} \sum_{t=1}^{T} \left[\alpha^{c} \pi_t^0 P_{d_t} + \sum_{i=1}^{n} (a_i P_{it}^2 + b_i P_{it} + c_i) \right]$$

subject to:

LME

$$\min \sum_{t=1}^{T} \sum_{i=1}^{n} \alpha_i P_{it}^2 + \beta_i P_{it} + \gamma_i$$

$$\sum_{i=1}^{n} P_{it} = P_{d_t} \; ; \forall t = 1 \ldots T, \; (\pi_t^0)$$

$$\underline{P_i} \le P_{it} \le \overline{P_i} \; ; \; \forall i = 1 \ldots n, \; \forall t = 1 \ldots T$$

$$P_{it} - P_{it-1} \le RUR_i \; ; \; \forall i = 1 \ldots n, \; \forall t = 1 \ldots T$$

$$P_{it-1} - P_{it} \le RDR_i \; ; \; \forall i = 1 \ldots n, \; \forall t = 1 \ldots T$$

Mathematical Formulation

$$\min_{P_{it}^{l}, P_{it}^{l2}, \Delta_{iyt}} \sum_{t=1}^{T} \left[\alpha^{c} \pi_{t}^{0} P_{d_t} + \sum_{i=1}^{n} a_i P_{it}^{l2} + b_i P_{it}^{l} + c_i \right]$$

subject to:

$$\min_{P_{it}^{l2}, P_{it}^{l}} \sum_{t=1}^{T} \sum_{i=1}^{n} \alpha_i P_{it}^{l2} + \beta_i P_{it}^{l} + \gamma_i$$

$$\sum_{i=1}^{n} P_{it}^{l} = P_{d_t} \; : (\pi_t); \; \forall t = 1 \ldots T$$

$$P_{it}^{l} - \sum_{y=1}^{Y} \Delta_{iyt} = 0 : (\lambda_{it}); \quad \forall i = 1 \ldots n, \; \forall t = 1 \ldots T$$

$$P_{it}^{l2} - \sum_{y=1}^{Y} m_{iy} \Delta_{iyt} = 0 : (\eta_{it}); \; \forall i = 1 \ldots n, \; \forall t = 1 \ldots T$$

$$\Delta_{iyt} \le \overline{\Delta}_{iy} : (\overline{\sigma}_{iyt}); \; \forall i = 1 \ldots n, \; \forall y = 1 \ldots Y, \; \forall t = 1 \ldots T$$

$$-\Delta_{iyt} \le 0 : (\underline{\sigma}_{iyt}); \; \forall i = 1 \ldots n, \; \forall y = 1 \ldots Y, \forall t = 1 \ldots T$$

$$P_{it}^{l} \le \overline{P}_{i} : (\overline{\kappa}_{it}); \; \forall i = 1 \ldots n, \; \forall t = 1 \ldots T$$

$$-P_{it}^{l} \le -\underline{P}_{i} : (\underline{\kappa}_{it}); \; \forall i = 1 \ldots n, \; \forall t = 1 \ldots T$$

$$P_{it}^{l} - P_{it-1}^{l} \le RUR_i \; : \; (\overline{\tau}_{it}); \; \forall i = 1 \ldots n, \; \forall t = 1 \ldots T$$

$$P_{it-1}^{l} - P_{it}^{l} \le RDR_i \; : \; (\underline{\tau}_{it}); \; \forall i = 1 \ldots n, \; \forall t = 1 \ldots T$$

Mathematical Formulation

$$\min_{\substack{P_{it}^{l},\, P_{it}^{l2},\, \pi_t,\, \overline{\kappa}_{it},\\ \underline{\kappa}_{it},\, \overline{\tau}_{it},\, \underline{\tau}_{it},\, \lambda_{it},\, \eta_{it},\\ \overline{\sigma}_{iyt},\, \underline{\sigma}_{iyt}}} \sum_{t=1}^{T}\left[\alpha^{c}\pi_t P_{d_t} + \sum_{i=1}^{n}\left(a_i P_{it}^{l2} + b_i P_{it}^{l} + c_i\right)\right]$$

subject to:

$$\sum_{t=1}^{T}\left[\pi_t P_{d_t} + \sum_{i=1}^{n}\left(\overline{\kappa}_{it}\overline{P}_i - \underline{\kappa}_{it}\underline{P}_i + \sum_{y=1}^{Y}\overline{\Delta}_{iy}\overline{\sigma}_{iyt}\right)\right] + \sum_{i=1}^{n}\left(\overline{\tau}_{i1}(RUR_i + P_{i0}^{l}) + \underline{\tau}_{i1}(RDR_i - P_{i0}^{l})\right)$$

$$+\sum_{t=2}^{T}\left[\sum_{i=1}^{n}\left(\overline{\tau}_{it}RUR_i + \underline{\tau}_{it}RDR_i\right)\right] = \sum_{t=1}^{T}\sum_{i=1}^{n}\alpha_i P_{it}^{l2} + \beta_i P_{it}^{l} + \gamma_i$$

$$\pi_t + \overline{\kappa}_{it} - \underline{\kappa}_{it} + \overline{\tau}_{it} - \overline{\tau}_{it+1} + \underline{\tau}_{it+1} - \underline{\tau}_{it} + \lambda_{it} = \beta_i;\ \forall i = 1\ldots n,\ \forall t = 1\ldots T-1$$

$$\pi_T + \overline{\kappa}_{iT} - \underline{\kappa}_{iT} + \overline{\tau}_{iT} - \underline{\tau}_{iT} + \lambda_{iT} = \beta_i;\ \forall i = 1\ldots n$$

$$\eta_{it} = \alpha_i;\ \forall i = 1\ldots n,\ \forall t = 1\ldots T$$

$$-\lambda_{it} - \eta_{it} m_{iy} + \overline{\sigma}_{iyt} - \underline{\sigma}_{iyt} = 0;\ \forall i = 1\ldots n,\ \forall y = 1\ldots Y, \forall t = 1\ldots T$$

Case Study and Results

- IEEE 30-bus system, 6-unit.
- Korean 140-unit system
- A Modeling Language for Mathematical Programming (AMPL).
- Commercial solver Cplex.
- Dynamic Dispatch

Case Study and Results

➢Hourly Power Output of Units— IEEE 30-Bus System

Unit	h1	h2	h3	h4	h5	h6
1	39.05	40.625	50	50	41.125	46
2	49.35	51.150	60	60	51.600	57.3
3	50.25	70	90	78.25	53.250	60
4	45.30	61.800	109.8	83.40	49.200	58.8
5	50.25	65.200	95.20	78.35	53.075	60
6	49.20	51.225	60	60	51.750	57.9

Total cost was $4636.71; corresponding emission was 124.938 kg. Using the proposed approach, the total cost increases to $4789.43 while the corresponding emission is decreases to 114.876 kg.

Case Study and Results

- Total CPU time for the 6-unit system: 0.86 s
- For the 140-unit system, an increase in the cost about 8% yeilds a decrease about 21% via 2.12 s.
  - The disjoint term has been neglected.
  - The nonconvex term has been neglected as well.

Concluding Remark

- A multi-objective function with conflicting objectives has been solved.
- Using the linearization and strong duality theorem, a single objective problem has been obtained.
- Global solution has been guaranteed.
- Since it is fast enough, it can be applied to online-based problems.

Question?

Special thanks

to the

Session Audiences