Comparison Study of Different Load Management Methods for Cost and Emission Reduction
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Abstract
To address the challenge of climate change, reducing emissions due to electric power generation and consumption has received increasing attention worldwide. The previous research efforts have been focused on emission reduction on the generation side, but often ignored the positive impacts through active load management. This paper explores the models of load management to reduce emissions. Three kinds of load management algorithms are studied and compared in this paper using IEEE 14-Bus system. The results show that the proposed temporal and spatial load management method is the best way for emission reduction.

Generator Cost Model

- Economic Cost Model
  \[ G_i = a_i P_{L,i}^2 + b_i P_{L,i} + c_i, \quad i = 1, \ldots, N_G \]
- Emission Cost Model
  \[ e_i = P_{CO_2} \times EF_{CO_2,i}, \quad i = 1, \ldots, N_G \]
- Combined Cost Model
  \[ F_i = a_i P_{L,i}^2 + b_i P_{L,i} + c_i + e_i P_{L,i}, \quad i = 1, \ldots, N_G \]

Temporal and Spatial Load Management

- Objective Function
  \[ C = \min \sum_{i} N_B E_i \]

- Constraints
  \[ P_{L,0,\text{min}} \leq P_{L,0} \leq P_{L,0,\text{max}}, \quad i = 1, \ldots, N_B \]
  \[ P_{G,0,\text{min}} \leq P_{G,0} \leq P_{G,0,\text{max}}, \quad i = 1, \ldots, N_G \]

  \[ \sum_{i=1}^{N_B} P_{L,0} = \sum_{i=1}^{N_G} P_{G,0} \]

Temporal only Load Management

- Objective Function
  \[ C = \min \sum_{i} E_i \]

- Constraints
  \[ P_{L,0,\text{min}} \leq P_{L,0} \leq P_{L,0,\text{max}}, \quad i = 1, \ldots, N_B \]
  \[ P_{G,0,\text{min}} \leq P_{G,0} \leq P_{G,0,\text{max}}, \quad i = 1, \ldots, N_G \]

  \[ \sum_{i=1}^{N_B} P_{L,0} = \sum_{i=1}^{N_G} P_{G,0} \]

Self-Optimizing Load Management

- Objective Function
  \[ C_i = \min \sum_{h=1}^{N_B} (LMP_{L,h} \times P_{L,i,h}), \quad i = 1, \ldots, N_B \]

- Constraints
  \[ P_{L,0,\text{min}} \leq P_{L,i,h} \leq P_{L,0,\text{max}}, \quad i = 1, \ldots, N_B \]
  \[ P_{G,0,\text{min}} \leq P_{G,i,h} \leq P_{G,0,\text{max}}, \quad i = 1, \ldots, N_G \]

  \[ \sum_{h=1}^{N_B} P_{L,i,h} = \sum_{h=1}^{N_G} P_{G,i,h} \]

- Cost
  \[ C = \sum_{h=1}^{N_B} LMP_{L,h} \times P_{L,i,h} \]

- Emission
  \[ E_{CO_2} = \sum_{h=1}^{N_B} P_{L,i,h} \times EF_{CO_2,i} \]

Simulation Results

Conclusions

- The TSLM and TLM perform on reducing the peak significantly. The SOLM can generate new peaks at different times which indicates the need for coordination among users for autonomous load management.
- All the load managements can reduce cost and emissions. The TSLM can achieve the best result.
- The higher emission price is implemented to the combined cost model, the more emission reduction could be achieved in all the methods.

References