Optimal Economic and Emission Dispatch of Photovoltaic Integrated Power System Using Firefly Algorithm

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Presentation Outline

- Introduction
- Objectives
- Problem Formulation
- Methodology
- Case Study
- Conclusion
Introduction

• The **Economic Load Dispatch (ELD)** problem is one of the important optimization problems in power system planning and operation.

• The aim of ELD problem is to minimize the cost of power generation and satisfied the power demand and operational limits.

• Due to environmental issues, the emission amount released by thermal power generation should be considered in minimizing the total cost generation as well.

• This make the power dispatch problem become multi-objective problem that called **Economic and Emission Load Dispatch (EELD)**

• Moreover, integration renewable energy such as Photovoltaic (PV) power plant in power system required fast and robust algorithm for solving EELD problem.
Economic-Emission Load Dispatch (EELD)

1. Power balance constraints
2. Generator limit constraints

Generator
Combination of thermal and PV power plant

Cost
Emission
Cost and Emission Characteristic of Thermal Power Plant

Cost

\[ Fc_i = (a_i + b_i P_i + c_i P_i^2) + d_i \sin(e_i (P_{\text{min}} - P_i)) \]

Emission

\[ Fe_i = \alpha_i + \beta_i P_i + \gamma_i P_i^2 + \varepsilon_i \exp(\delta_i P_i) \]
Cost and Emission Characteristic of Thermal Power Plant

![Graph showing the relationship between Real Power, Fuel Cost, and Emission. The graph indicates a decrease in Fuel Cost and an increase in Emission as Real Power increases.](image-url)
Cost Function of PV Power Plant

\[ \text{Solar Cost} = \sum_{j=1}^{m} (\text{PU cost}_j \times \text{PPV}_j \times \text{Us}_j) \]

where,

- \( \text{PU cost}_j \): Per unit of \( j^{th} \) solar plant
- \( \text{PPV} \): Power available from \( j^{th} \) solar plant
- \( \text{Us}_j \): Status of \( j^{th} \) solar plant either 1 (ON) or 0 (OFF)
- \( M \): Number of solar panels

\[ \text{PPV} = P_{\text{rated}} \{1 + (T_{\text{ref}} - T_{\text{cell}}) \times \alpha \} \times \frac{S_i}{1000} \]

where,

- \( P_{\text{rated}} \): Rated power
- \( T_{\text{ref}} \): Reference temperature
- \( T_{\text{cell}} \): Cell temperature
- \( \alpha \): Temperature coefficient
- \( S_i \): Incident solar radiation
Objectives

1. To formulate the EELD problem for thermal and PV power plant.
2. To investigate the performance of Firefly Algorithm (FA) for solving EELD problem with integrated PV power plant.
Methodology

Start

- Problem formulation

Develop FA algorithm

- Apply FA for Cost Minimization

- Apply FA for emission minimization

Develop FA for cost and emission minimization EELD

Determine the best compromise solution by using fuzzy-based mechanism

Analyse the results in term of optimal solution, convergence characteristics and robustness

Compare the performance of FA algorithm for cost and emission minimization

End

\[ F = w \sum_{i=1}^{ng} F_i(P_i) + (1-w)h \sum_{i=1}^{ng} E_i(P_i) \]

\[ u_{ij} = \begin{cases} 
1 & f_j(X_i) \leq f_j^{\min} \\
\frac{f_{j}^{\max} - f_j(X_i)}{f_{j}^{\max} - f_{j}^{\min}} & f_j^{\min} \leq f_j(X_i) \leq f_j^{\max} \\
0 & f_j(X_i) \leq f_j^{\max} \end{cases} \]

\[ \text{F} = \sum_{i=1}^{ng} F_i + \sum_{i=1}^{ng} E_i \]
Problem Formulation

Objective Function:

Minimize Total Cost,
\[ \text{Min } F_T = \sum_{i=1}^{n} (a_i P_i^2 + b_i P_i + c_i) + \sum_{j=1}^{m} (PU\text{cost}_j \times \text{PPV}_j \times U_{s_j}) \]

Minimize Emission,
\[ \text{Min } E_i(P_i) = \sum_{i=1}^{n} (d_i P_i^2 + e_i P_i + \gamma_i) \]

Combine Cost & Emission
\[ \text{Min } Y = w \left[ \sum_{i=1}^{n} (a_i P_i^2 + b_i P_i + c_i) + \sum_{j=1}^{m} (PU\text{cost}_j \times \text{PPV}_j \times U_{s_j}) + (1 - w) h_i \sum_{i=1}^{n} (E_i P_i) \right] \]

Constraints:

Power balance constraints
\[ \sum_{i=1}^{n_\text{g}} P_i = P_D + P_L \]

Generator limit constraints
\[ P_i^{\min} \leq P_i \leq P_i^{\max} \]

PV Generation Constraints
\[ \sum_{j=1}^{m} \text{PPV} \times U_{s_j} \leq 0.3 \times P_D \text{ With } \forall U_{s_j} \in \{0, 1\} \]
FA Algorithm for EELD

1. Define the objective function.
2. Define Firefly Algorithm.
3. Generate initial Firefly population respect to the constraint in (10), (11) and (12).
4. Evaluate fitness of all fireflies from the objective function in equation (2), (4) and (7).
5. Less bright firefly moves toward brighter one and brightest firefly move randomly (13) and (14).
6. Rank and update position and evaluate fitness of all firefly respect to constraints in equations (10), (11) and (12).
7. Maximum iteration number reached?
   - Yes: Optimal solution
   - No: Select m, r, e (15)

\[ x_{i}^{t+1} = x_{i}^{t} + \beta_{r} (x_{j}^{t} - x_{i}^{t}) + \alpha_{t} e_{i}^{t} \]

\[ \beta_{r} = \beta_{m} e^{-\gamma m} \]
The purpose of this study is to:
1. Minimize Total Cost,
2. Minimize Total Emission,
3. Minimize Combine Cost & Emission

Test System

*Cost and emission coefficients can be found in the paper*
**PV Input Data**

Table 1: Power demand, solar radiation and temperature

<table>
<thead>
<tr>
<th>Hours</th>
<th>Power demand (MW)</th>
<th>Global solar radiation (W/m²)</th>
<th>Temperature (°C)</th>
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<tbody>
<tr>
<td>1</td>
<td>965</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>1142</td>
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<td>29</td>
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<td>3</td>
<td>1177</td>
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<td>4</td>
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<td>5</td>
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<td>5.4</td>
<td>28</td>
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<td>8</td>
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<tr>
<td>12</td>
<td>1240</td>
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<tr>
<td>13</td>
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<td>37</td>
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<td>14</td>
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<td>848.2</td>
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</tbody>
</table>

Table 2: Solar PV power rate

<table>
<thead>
<tr>
<th>Plant</th>
<th>Power rated (MW)</th>
<th>Solar Unit rate ($/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV₁</td>
<td>20</td>
<td>0.22</td>
</tr>
<tr>
<td>PV₂</td>
<td>25</td>
<td>0.23</td>
</tr>
<tr>
<td>PV₃</td>
<td>25</td>
<td>0.23</td>
</tr>
<tr>
<td>PV₄</td>
<td>30</td>
<td>0.24</td>
</tr>
<tr>
<td>PV₅</td>
<td>30</td>
<td>0.24</td>
</tr>
<tr>
<td>PV₆</td>
<td>35</td>
<td>0.25</td>
</tr>
<tr>
<td>PV₇</td>
<td>35</td>
<td>0.26</td>
</tr>
<tr>
<td>PV₈</td>
<td>40</td>
<td>0.27</td>
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<tr>
<td>PV₉</td>
<td>40</td>
<td>0.27</td>
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<tr>
<td>PV₁₀</td>
<td>40</td>
<td>0.275</td>
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<tr>
<td>PV₁₁</td>
<td>40</td>
<td>0.28</td>
</tr>
<tr>
<td>PV₁₂</td>
<td>40</td>
<td>0.28</td>
</tr>
<tr>
<td>PV₁₃</td>
<td>40</td>
<td>0.28</td>
</tr>
</tbody>
</table>
1. Minimize Total Cost

Hourly cost and corresponding emission for cost minimization using FA

Total cost for 24 h: 1,722,707.577 ($/h)
Corresponding total emission: 31,275.565 (kg/h)
2. Minimize Total Emission

Hourly emission and corresponding cost for emission minimization using FA

Total emission for 24 h: 24,128.104 (kg/h)
Corresponding total cost: 2,325,713.049 ($/h)
3. Minimize Combine Cost & Emission - EELD

Pareto Front obtained with WSM for hours 12.00

EELD best solution
Comparison

Robustness of FA for cost and emission minimization (hour 11)

Total cost versus total emission
Comparison of Total cost and emission obtained by FA for different objective functions

<table>
<thead>
<tr>
<th></th>
<th>Total Cost ($/h)</th>
<th>Total Emission (kg/h)</th>
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<tbody>
<tr>
<td>Minimize Cost</td>
<td>1722707.577</td>
<td>31275.565</td>
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<tr>
<td>Minimize SCEED</td>
<td>1925391.125</td>
<td>27659.384</td>
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<tr>
<td>Minimize Emission</td>
<td>2325713.049</td>
<td>24128.104</td>
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</table>
Conclusion

• In this paper, an **Firefly Algorithm Algorithm (FA)** is proposed to solve a combined economic and emission load dispatch (EELD) problem in power generation with PV power plant.

• It found that the total cost that obtained for minimizing cost is 1722707.577 ($/h) with corresponding emission of 31275.565 (kg/h). For minimizing emission, total cost obtained was 2325713.049 ($/h) and produced emission amount 24128.104 (kg/h).

• It shows that the proposed FA can **provide significant cost and emission reduction/saving** for EELD problem.

• Thus, it can be concluded that **FA has good potential** to be implemented in other power system optimization problems especially in optimal power dispatch area.
ACKNOWLEDGEMENT
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Thank You...