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Application of Particle Swarm Optimization to Economic Dispatch Problem: Advantages and Disadvantages

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Contents

- Introduction
- ED Problem Formulations
- Survey of PSO Applications to ED Problems
- Advantages and Disadvantages of PSO
- Conclusions

Introduction (1)

- Overview of Particle Swarm Optimization (1)
  - Branch of Swarm Intelligence
    - Swarm Intelligence Techniques : PSO (Eberhart and Kennedy, 1995), Ant Colony Optimization (Dorigo, 1992), Stochastic Diffusion Search (Bishop, 1989), etc.
  - Basic Characteristics of PSO
    - Relatively recently developed Heuristic AI-Optimization technique
    - Analogy of school of fish and flock of bird
    - Population based parallel search algorithm
    - Each particle or agent searches, based on its own experience and its neighbor's experiences

Introduction (2)

- Overview of Particle Swarm Optimization (1)
  - Advantages
    - Simple concept
    - Easy implementation
    - Robustness to control parameters
    - Computational efficiency, etc.

Introduction (3)

- **Representation of each particle in optimization problems with *n*-dimensional search space**
  - **Position and velocity of particle-*i*:**

$$X_i = \left(x_{i1}, \cdots, x_{in}\right) \qquad V_i = \left(v_{i1}, \cdots v_{in}\right)$$

  - **Best position of particle-*i*:** $Pbest_i = \left(x_{i1}^{Pbest}, \cdots, x_{in}^{Pbest}\right)$

  - **Its neighbor's best position:** $Gbest = \left(x_1^{Gbest}, \cdots, x_n^{Gbest}\right)$

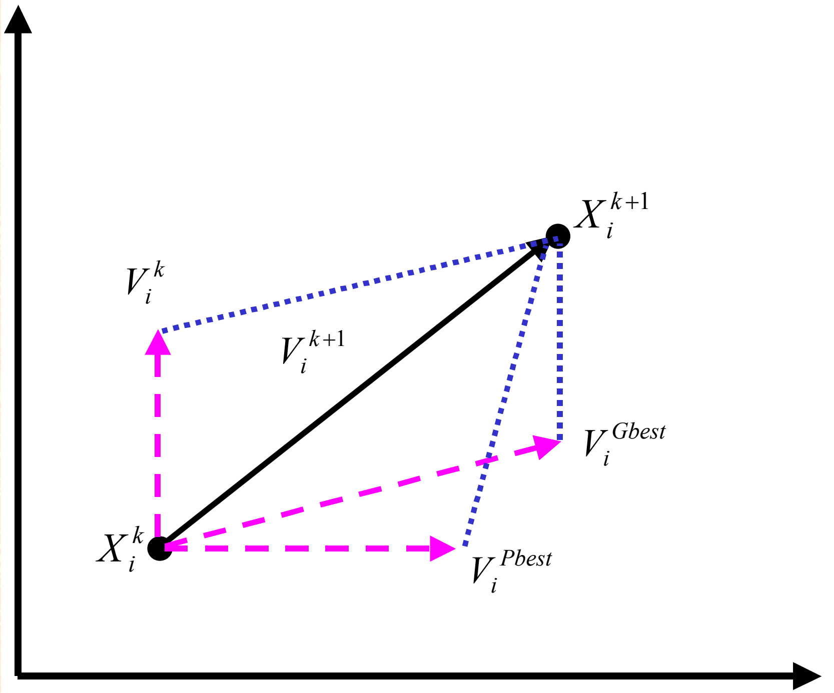
Introduction (4)

- **General update rule (update of velocity and position)**
  - **Velocity update of particle-*i*:**

$$V_i^{k+1} = \omega V_i^k + c_1 r_1 \times (Pbest_i^k - X_i^k) + c_2 r_2 \times (Gbest^k - X_i^k)$$

  - **Position update of particle-*i*:**

$$X_i^{k+1} = X_i^k + V_i^{k+1}$$



Introduction (5)

- Control Parameters
  - Acceleration coefficients (c_1, c_2)
    - Constant values where normally $c_1 + c_2 = 4.0$ and $c_1 = c_2$ (Ozcan and Mohan, 1999)
    - Problem dependent coefficients
  - Inertia weight factor (ω)
    - Constant approach : Suggested by Shi (1998) and Eberhart (1999)
    - Dynamically changing approach (linearly decreasing case): changing from exploring mode to exploiting mode

$$\omega = \omega_{\max} - \frac{\omega_{\max} - \omega_{\min}}{Iter_{\max}} \times Iter$$

Introduction (6)

- **Overview of Economic Dispatch Problems and Application Techniques**
  - **Nonlinear and non-smooth optimization problems when considering valve-point effects, multi-fuels, prohibited operating zones, etc.**
    - **Limitation of mathematical-based approaches (gradient information)**
    - **Limitation of Dynamic Programming (Curse of Dimensionality)**

Introduction (7)

- Overview of Economic Dispatch Problems and Application Techniques
  - Alternatives (Heuristic AI-based techniques)
    - Genetic Algorithms (GAs)
    - Evolutionary Programmings (EPs)
    - Tabu Searches (TPs)
    - Neural Networks (NNs)
    - Particle Swarm Optimizations (PSOs)

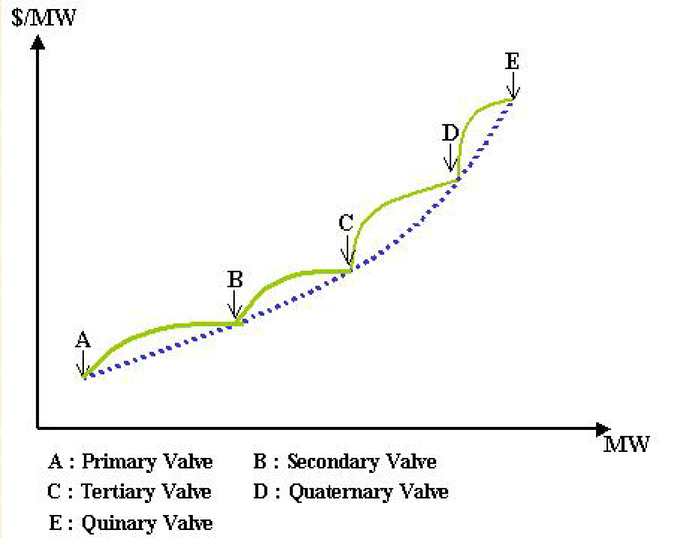
ED Problem Formulations (1)

- **Conventional quadratic cost function**
  - **Objective function (analytical function)**

$$F_T = \sum_{i=1}^{N} F_i(P_i) \qquad F_i(P_i) = a_i + b_i P_i + c_i P_i^2$$

- **Valve-point effects**

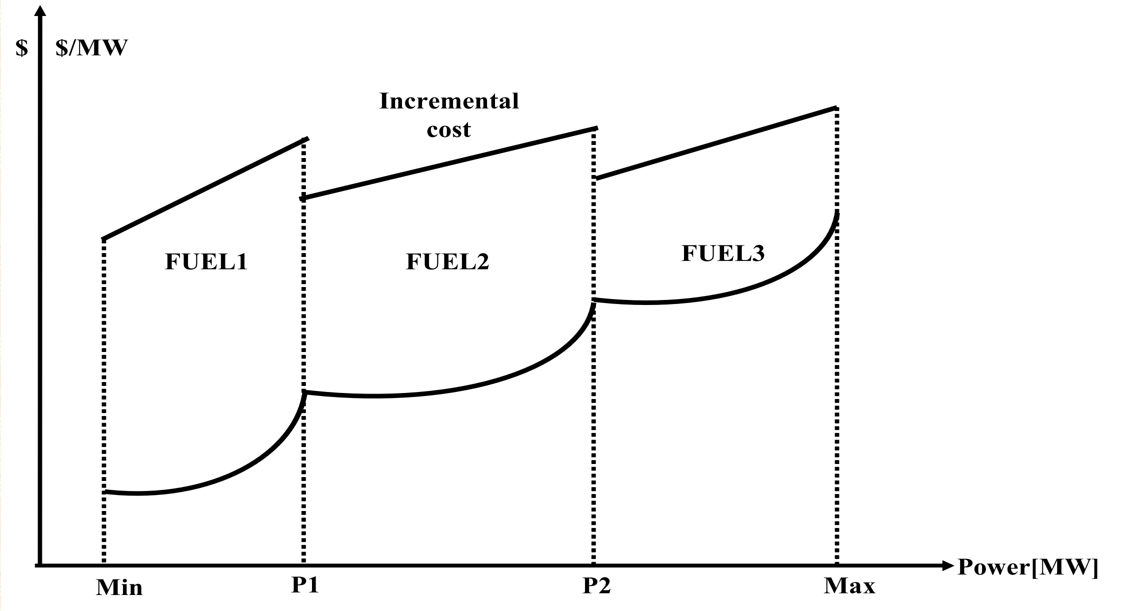
$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 + \left| e_i \times \sin(f_i \times (P_{i,\min} - P_i)) \right|$$



ED Problem Formulations (2)

- **Cost function with multiple fuels**
  - **Objective function**

$$F_i(P_i) = \begin{cases} a_{i1} + b_{i1}P_i + c_{i1}P_i^2 & if \quad P_{i\min} \le P_i \le P_{i1} \\ a_{i2} + b_{i2}P_i + c_{i2}P_i^2 & if \quad P_{i1} \le P_i \le P_{i2} \\ \vdots & \vdots \\ a_{in} + b_{in}P_i + c_{in}P_i^2 & if \quad P_{in-1} \le P_i \le P_{i\max} \end{cases}$$



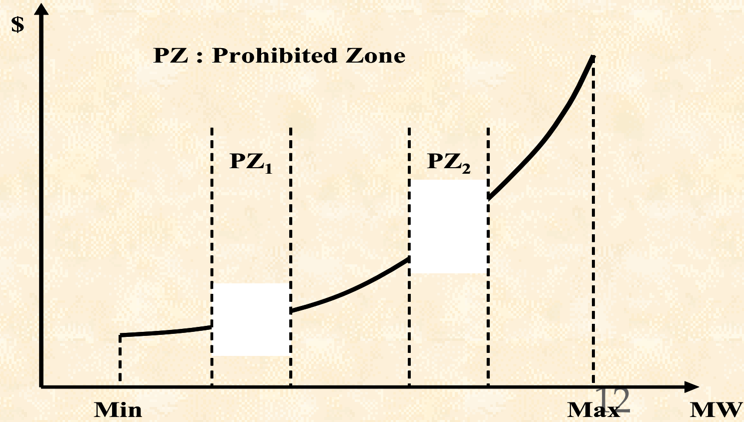
ED Problem Formulations (3)

- **Constraints**
  - **Equality constraint (active power balance equation)**

$$\sum_{i=1}^{N} P_i = P_D + P_{Loss}$$

  - **Inequality constraints (1)**
    - **Minimum and Maximum power limits:** $P_{i,\min} \le P_i \le P_{i,\max}$
    - **Ramp rate limits:** $P_i - P_i^0 \le DR_i \quad P_i - P_i^0 \le UR_i$
    - **Spinning reserve requirements:** $\sum_{i=1}^{N} \{Min\,(P_{i,\max} - P_i, UR_i)\} \ge S_R$
    - **Generator prohibited operating zones:**

$$P_i \in \begin{cases} P_{i,\min} \le P_i \le P_{i,1}^{l} \\ P_{i,k-1}^{u} \le P_i \le P_{i,k}^{l}, \qquad k = 2,3,\cdots, N_{PZ,i} \\ P_{i,N_{PZ,i}}^{u} \le P_i \le P_{i,\max} \end{cases}$$



    - **Line flow constraints:**

$$\left| P_{Lf,k} \right| \le P_{Lf,k}^{\max},$$

Survey of PSO Applications to ED Problems (1)

- Practical ED Problems
  - Objective function
    - Cost functions with valve-point and multi-fuel impacts
  - Constraints
    - Nonlinear equality and inequality constraints
- Park, Lee, Shin & Lee (2005)
  - Non-smooth cost functions - valve-point and multi-fuel effects
  - Suggested a <u>modified PSO scheme</u>, employing constraint treatment technique and dynamic search space reduction strategy
  - Parameter Values
    - Valve-point effect problems: population = 20, initial inertia weight (w_{max}) = 1.0, final inertia weight (w_{min}) = 0.5, acceleration coefficients = 2.0
    - Multi-fuel effect problems: population = 30, initial inertia weight (w_{max}) = 0.5, final inertia weight (w_{min}) = 0.1, acceleration coefficients = 2.0

Survey of PSO Applications to ED Problems (2)

- El-Gallad, et al. (2002)
  - Added the constraints of system spinning reserve and generator prohibited operating zones. Applied the conventional PSO technique
- Giang (2003)
  - Additional constraints of generator ramp rate limits on the El-Gallad's
  - PSO technique with the fitness function values in [0.1]
  - Parameter Values
    - population = 100, initial inertia weight (w_{max}) = 0.9, final inertia weight (w_{min}) = 0.4, acceleration coefficients = 2.0
- Giang (2004)
  - Dynamic EDs considering spinning reserve, ramp rate, prohibited operating zones, and line flow limits.

Survey of PSO Applications to ED Problems (3)

- Victoire and Jeyakumar (2005)
  - Solved dynamic ED problems combining PSO and Sequential Quadratic Programming (SQP)
    - Main Optimizer: PSO, Local Optimizer: SQP
  - Parameter Values
    - population = 100, initial inertia weight (w_{max}) = 1.3, final inertia weight (w_{min}) = 0.7, acceleration coefficients = 2.0

Survey of PSO Applications to ED Problems (4)

- **Comparison of simulation results (1)**
  - **40-generator system with valve-point effects - demand is 10,500MW**

	CEP	FEP	MFEP	IFEP	PSO
Min. Cost	123488.29	122679.71	122647.57	122624.35	122252.27

CEP (Classical Evolutionary Programming), FEP (fast EP), MFEP (modified FEP), IFEP (improved FEP)

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  - Y. M. Park, J. R. Won, and J. B. Park, "A new approach to economic load dispatch based on improved evolutionary programming," *Eng. Intell. Syst. Elect. Eng. Commun.*, Vol. 6, No. 2, pp. 103-110, June 1998.
  - Sinha, R. Chakrabarti, and P. K. Chattopadhyay, "Evolutionary programming techniques for economic load dispatch," *IEEE Trans. on Evolutionary Computations*, Vol. 7, No. 1, pp. 83-94, Feb. 2003.
  - J. B. Park, K. S. Lee, J. R. Shin, and K. Y. Lee, "A particle swarm optimization for economic dispatch with nonsmooth cost functions," *IEEE Trans. on Power Systems*, Vol. 20, No. 1, pp. 34-42, Feb. 2005.

Survey of PSO Applications to ED Problems (5)

- **Comparison of simulation results (2)**
  - **15-generator system with prohibited operating zones**

	GA	PSO
Total power output [MW]	2668.4	2662.4
Total line loss [MW]	38.2782	32.4306
Total generation cost [$]	33,113	32,858

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- Z. L. Gaing, "Particle swarm optimization to solving the economic dispatch considering the generator constraints," *IEEE Trans. on Power Systems*, Vol. 18, No. 3, pp. 1187-1195, Aug. 2003.
- H. Chen and H. C. Chang, "Large-scale economic dispatch by genetic algorithm," *IEEE Trans. on Power Systems*, Vol. 10, No. 4, pp. 1919-1926, Nov. 1995.

Survey of PSO Applications to ED Problems (6)

- **Comparison of simulation results (3)**
  - **10-generator system with multi-fuels**

S	U	MHNN		AHNN		IEP		PSO	
		F	GEN	F	GEN	F	GEN	F	GEN
1	1	2	224.5	2	225.7	2	219.5	2	218.3
	2	1	215.0	1	215.2	1	211.4	1	211.7
	3	3	291.8	1	291.8	1	279.7	1	280.7
	4	3	242.2	3	242.3	3	240.3	3	239.6
2	5	1	293.3	1	293.7	1	276.5	1	278.5
	6	3	242.2	3	242.3	1	239.9	3	239.6
	7	1	303.1	1	302.8	1	289.0	1	288.6
3	8	3	242.2	3	242.3	3	241.3	3	239.6
	9	1	355.7	1	355.1	3	425.1	3	428.5
	10	1	289.5	1	288.8	1	277.2	1	274.9
TP			2699.7		2700.0		2700.0		2700.0
TC			626.12		626.240		623.851		623.809

- **References**

  - J. B. Park, K. S. Lee, J. R. Shin, and K. Y. Lee, "A particle swarm optimization for economic dispatch with nonsmooth cost functions," *IEEE Trans. on Power Systems*, Vol. 20, No. 1, pp. 34-42, Feb. 2005.

Advantages and Disadvantages of PSO (1)

- PSO-based approach is considered as the one of the most powerful methods for resolving the non-smooth global optimization problems
- Main Advantages of PSO-based Approaches
  - A derivative-free technique
  - Easy in its concept and coding implementation
  - Less sensitive to the nature of the objective function
  - Limited number of parameters. Also, less sensitive to parameters
  - Less dependent on initial points
  - Generate high-quality solutions with shorter calculation time and stable convergence characteristics

Advantages and Disadvantages of PSO (2)

- Disadvantages of PSO-based Approaches
  - Lacking somewhat of a solid mathematical foundation for analysis,
  - Some limitations in real-time ED applications, such as in the 5-minute dispatch with network constraints, due to relatively longer computation time (Possibility for the off-line real-world ED problems such as in the Day-ahead electricity markets)
  - Still having the problems of dependency on initial conditions, parameter values, difficulty in finding the optimal design parameters, stochastic characteristics of the final outputs

Conclusions

- This discussion is to survey and summarize the applications of PSO to ED problems including the advantages and disadvantages of the approaches
- PSO techniques
  - Much attention in various application areas including ED problems
  - Outperforming other existing heuristic optimization techniques as well as mathematical methods on the non-smooth ED problems
  - Still needing further research and development to improve its performance and to obtain robustness
  - For the application to real-world on-line ED problems, it is necessary to combine the conventional mathematical approach with the PSO methods