Biogeography-Based Optimization of Power Flow

All authors should be listed on the first page, just like in your paper

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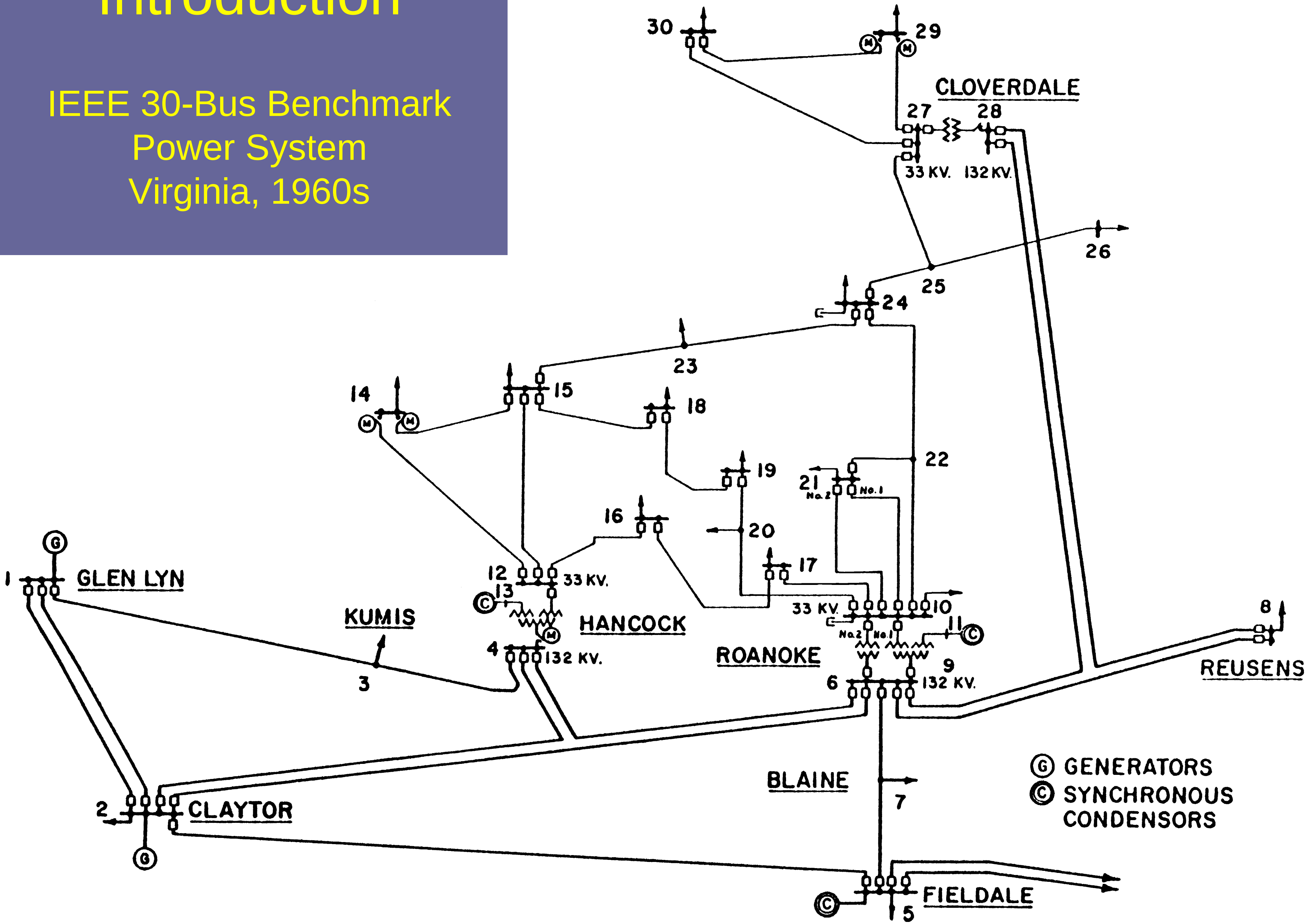
Outline

I. Introduction
II. Power Flow Problem
III. Simulation Results
IV. Conclusion

Introduction

IEEE 30-Bus Benchmark
Power System
Virginia, 1960s

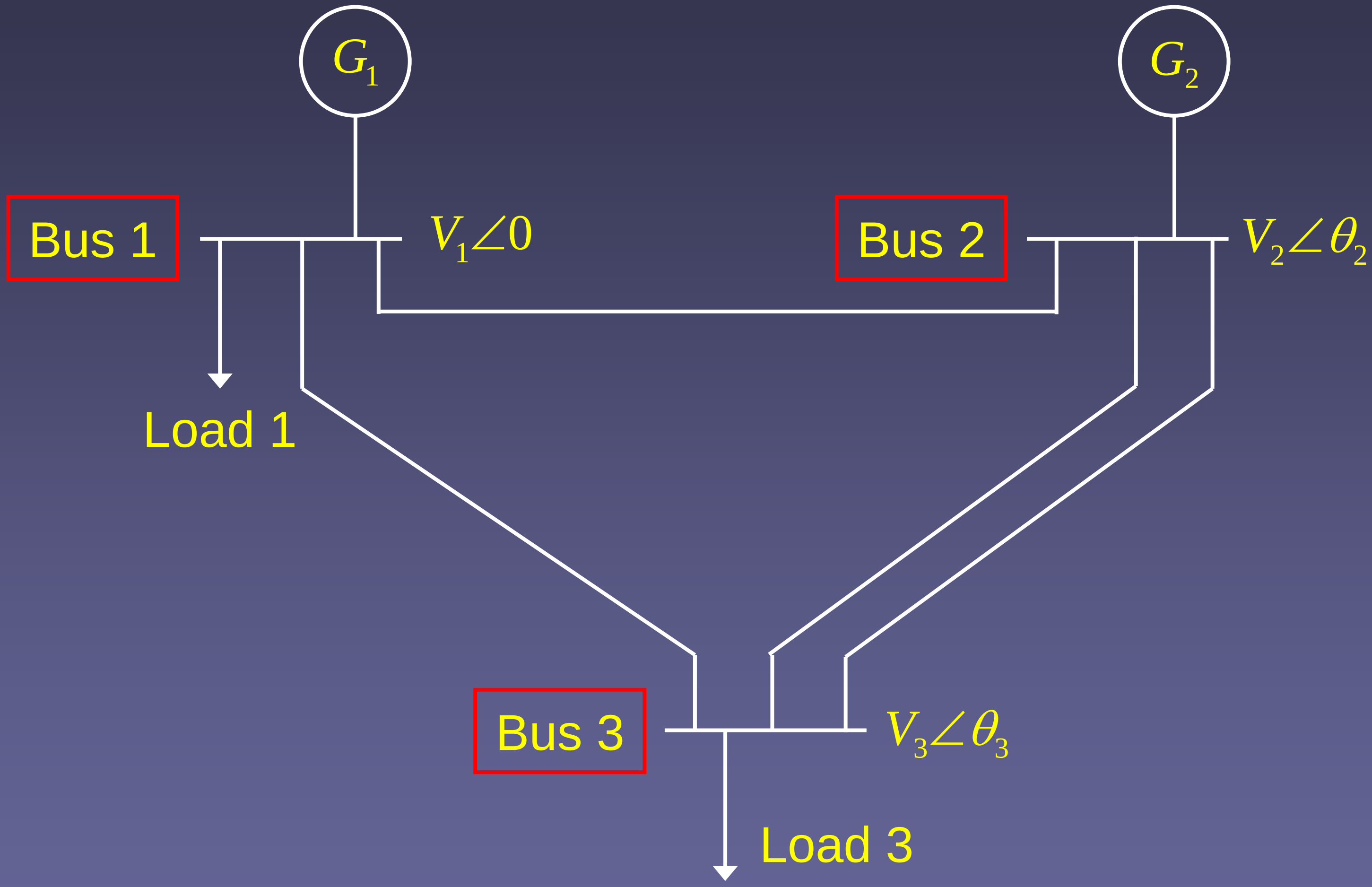


Introduction

Power System Design Problems

- Large number of variables (5,000) and constraints (10,000)
- Nonlinear and non-differentiable
- Multiple local minima
- Numerical methods unreliable under high loads and faults

Power Flow Problem



Power Flow Problem

30-Bus System

Bus voltage magnitude and phase angle vectors:

$$\mathbf{V} = \left(V_1, V_2, \ldots, V_{30}\right), \qquad \boldsymbol{\theta} = \left(\theta_1, \theta_2, \ldots, \theta_{30}\right)$$

60 unknowns

Bus i
2 Constraint
Eqs

$$P_i\left(\mathbf{V}, \boldsymbol{\theta}\right) = V_i \sum_{j \in N_b} V_j \left(G_{ij} \cos(\theta_{ij}) - B_{ij} \sin(\theta_{ij})\right)$$

$$Q_i\left(\mathbf{V}, \boldsymbol{\theta}\right) = V_i \sum_{j \in N_b} V_j \left(G_{ij} \sin(\theta_{ij}) - B_{ij} \cos(\theta_{ij})\right)$$

30x2 = 60
Constraint
Eqs

Power Flow Problem

Cost Function = Power / Voltage Mismatch (Ideally = 0)

$$\Delta = \left| \text{Estimated} - \text{Specified} \right|$$

Numerically Heuristically Design

$$\Delta P_i = \left| P_i^{\text{est}} - P_i^{\text{sp}} \right|$$

$$\Delta Q_i = \left| Q_i^{\text{est}} - Q_i^{\text{sp}} \right|$$

$$\Delta V_i = \left| V_i^{\text{est}} - V_i^{\text{sp}} \right|$$

$$\min_{\mathbf{V},\boldsymbol{\theta}} \left\{ \sum_{i \in Gen} \Delta P_i^2 \left(\mathbf{V}, \boldsymbol{\theta} \right) + \lambda_Q \sum_{i \in PQ} \Delta Q_i^2 \left(\mathbf{V}, \boldsymbol{\theta} \right) + \lambda_V \sum_{i \in PV} \Delta V_i^2 \left(\mathbf{V} \right) \right\}$$

Simulation

IEEE 30-Bus

Each Chromosome/Island - 60 genes

$$\left(V_1, V_2, \ldots, V_{30}, \theta_1, \theta_2, \ldots, \theta_{30}\right)$$

$$V_1, V_2, V_5, V_8, V_{13}, \theta_1 \quad \text{--- Fixed}$$

Population = 100

Generations = 100

Monte Carlo Trials = 1000

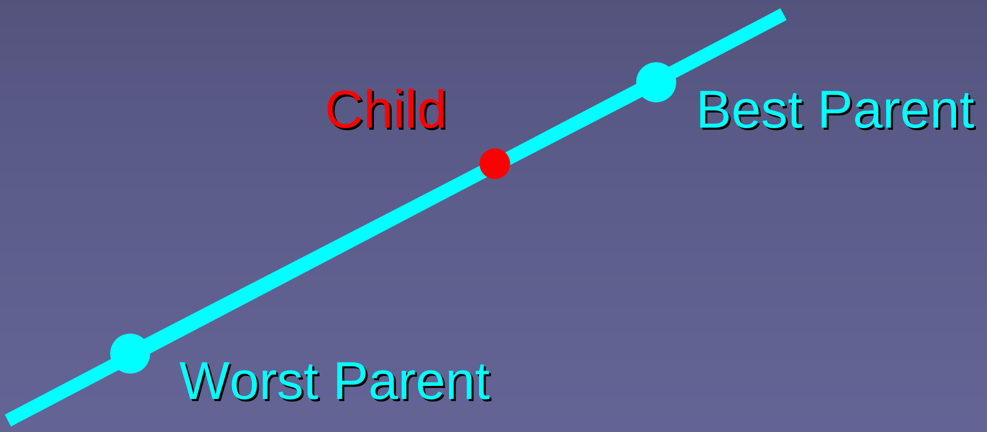
Probability of Mutation = 0.001

Simulation

Heuristic Crossover for GA

$$\alpha \sim U(0,1)$$

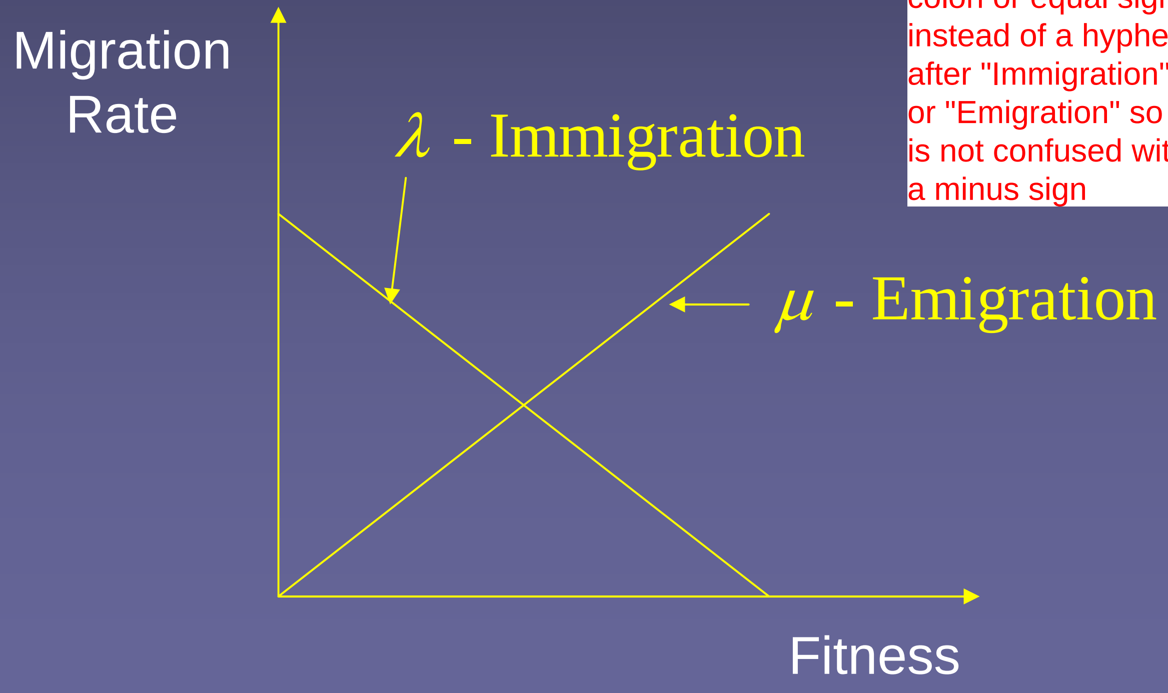
$$\text{Child} = \text{Best Parent} + \alpha\left(\text{Best Parent} - \text{Worst Parent}\right)$$



Simulation

Migration Scheme for BBO

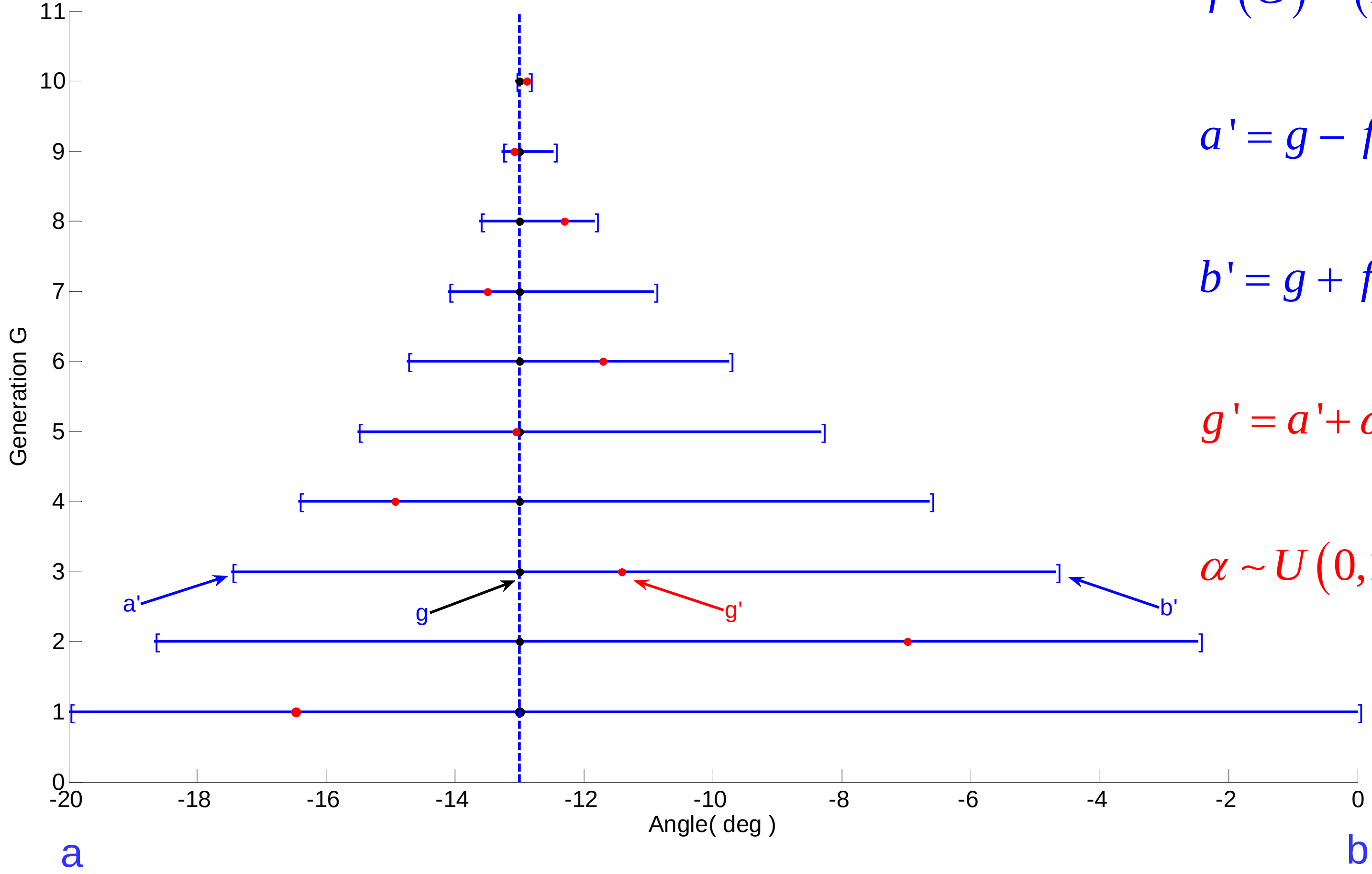
Immigration and Emigration:
Probabilistically determined by lambda, mu, and fitness



more clear to use a colon or equal sign instead of a hyphen after "Immigration" or "Emigration" so it is not confused with a minus sign

Simulation

Non-Uniform Mutation for GA and BBO



$$f(G) = (1 - G / G\max)^2$$

$$a' = g - f(G)(g - a)$$

$$b' = g + f(G)(b - g)$$

$$g' = a' + \alpha(b' - a')$$

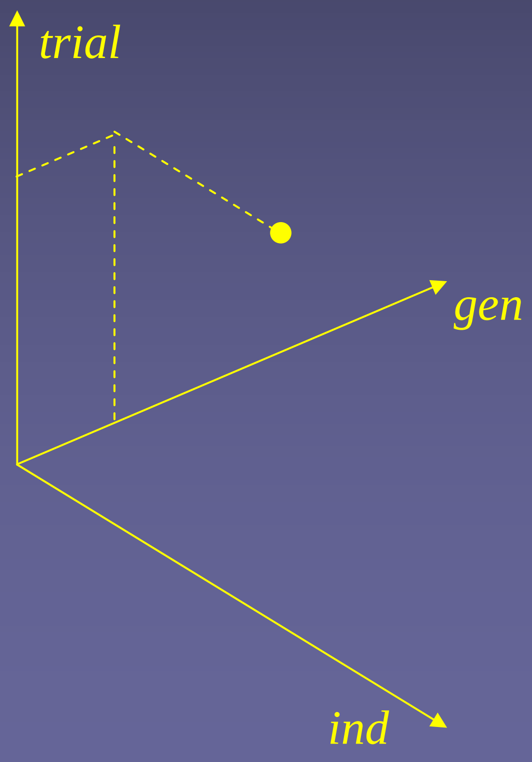
$$\alpha \sim U(0,1)$$

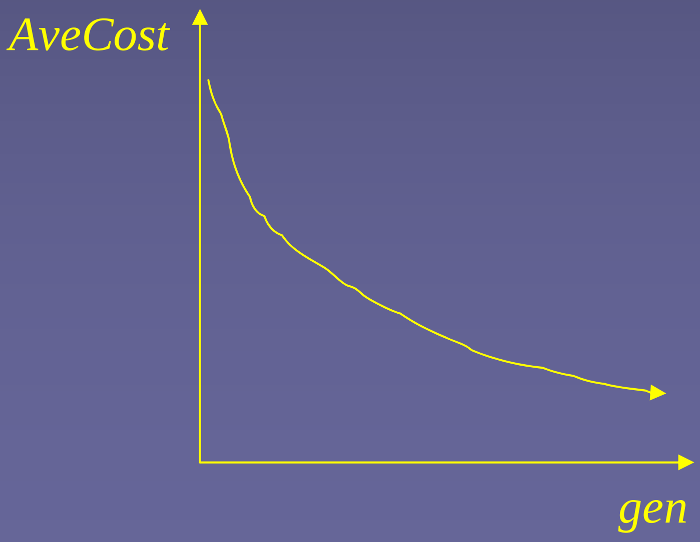
Simulation

GA and BBO Performance

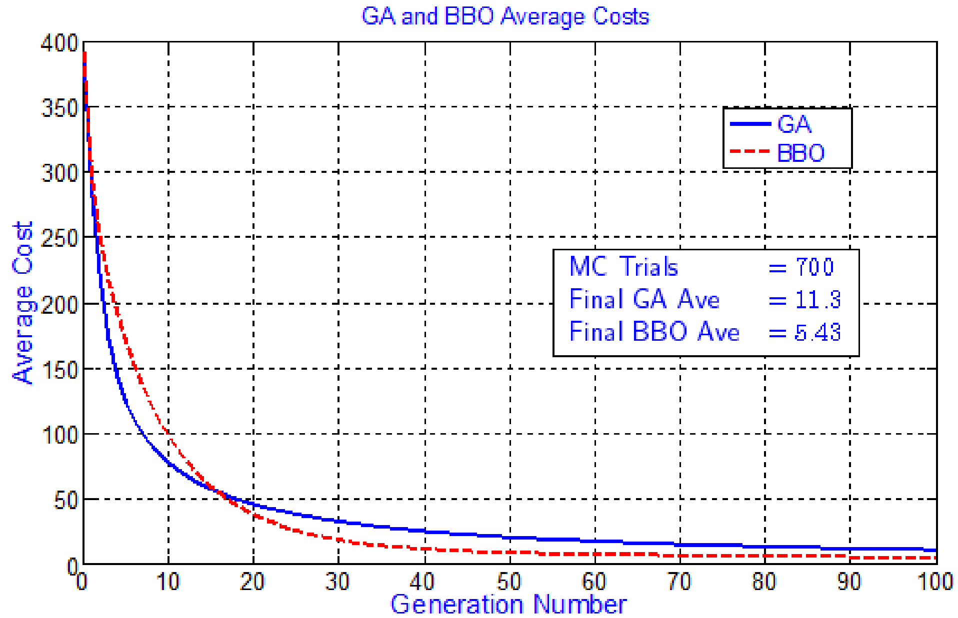
$$cost = cost\left(individual,\ generation,\ trial\right)$$

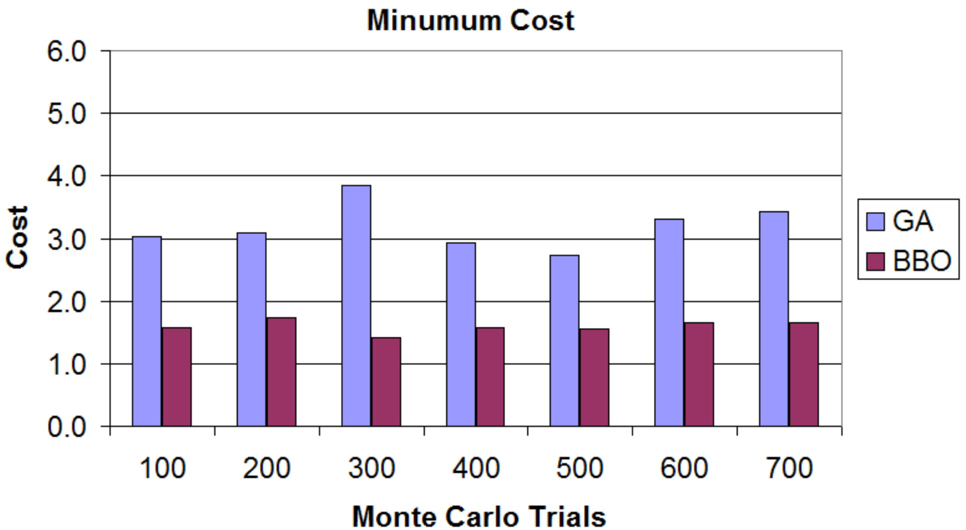
$$AveCost\left(gen\right) = \underset{trials}{\text{ave}}\left(\underset{ind}{\text{ave}}\left[cost\left(ind,\ gen,\ trial\right)\right]\right)$$





Simulation


GA and BBO Average Costs
Average Cost
Generation Number
GA
BBO
MC Trials = 700
Final GA Ave = 11.3
Final BBO Ave = 5.43
0
50
100
150
200
250
300
350
400
0
10
20
30
40
50
60
70
80
90
100


Minumum Cost
Cost
Monte Carlo Trials
GA
BBO
0.0
1.0
2.0
3.0
4.0
5.0
6.0
100
200
300
400
500
600
700

Conclusion

- BBO performs better than GA on Power Flow problem
- First application of BBO to engineering problem
- Not restricted to differentiable system equations
- Need statistical significance of result
- Need to apply to more difficult Optimal Power Flow problem

Thank you !