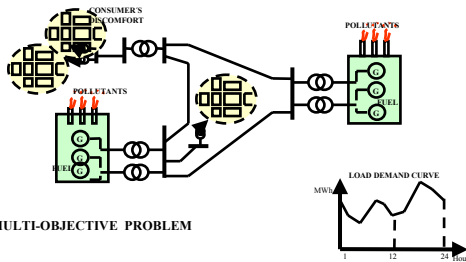


Introduction

Environmental/economic dispatch is a multi-objective problem with conflicting objectives since emission minimization conflicts with fuel cost minimization.



Objectives

• Fuel Cost Minimization

$$C = \sum_{i=1}^n (a_i + b_i P_{G_i} + c_i P_{G_i}^2)$$

• SO₂ Emission Minimization

$$E_{SO_2} = \sum_{i=1}^n (a_{SO_2} P_{G_i}^2 + b_{SO_2} P_{G_i} + c_{SO_2})$$

Constraints

• Power balance

$$\sum_{i=1}^n P_i - P_D - P_{loss} = 0$$

• Operating limits of generators

$$P_{G_{min}} \leq P_{G_i} \leq P_{G_{max}}$$

Multi-Objective Problem

The nonlinear constrained multi-objective optimization problem can be summarized as follows.

$$\begin{aligned} & \text{Minimize } [C, E_{SO_2}] \\ & \text{subject to: } h(P_{G_i}) = 0 \\ & P_{G_{min}} \leq P_{G_i} \leq P_{G_{max}} \end{aligned}$$

Where h is the problem constraint

Evolutionary Algorithms

Features:

- Maintain a set of solution candidates
- Undergo Selection Procedure
- Use Sampling Methods

Terms:

- Population – Set of solutions, Individual – Each solution
- Generation – Successive Population, Selection – Survival of the fittest
- Genotype – Design Variable, Phenotype – Objective or Constraints

Genetic Algorithm (GA)

Some Advantages:

- GA permits capturing of multiple optimal solutions. Such solutions can facilitate conflicting multi-objective function optimization. So this approach gives information regarding trade off.
- GA does not require any prior knowledge, space limitations, or special properties of the function to be optimized such as smoothness, convexity, unimodality, or existence of derivatives.
- GA converges to the global optimum with a high degree of consistency, regardless of the specification of the initial population.

Multi-Objective Genetic Algorithm

- Step 1: Initialize the population Po of size N with iteration counter t = 0
- Step 2: Decode strings to solutions in the phenotype world. Calculate the values of the n objectives for each solution and update the tentative set of non dominated solutions
- Step 3: Operate constrained binary tournament selection operations to select two parent solutions
- Step 4: Apply simulated binary crossover operator to each of the selected pairs in step 3 with crossover probability Pc
- Step 5: Apply a bitwise mutation operator to each of generated strings with mutation probability Pm
- Step 6: The populations of parent and offspring solutions are combined and then ranked from best class of solutions to worst by elite preservation
- Step 7: Continue the iterations until it reaches pre specified termination criterion (maximum number of generations)

Three Thermal Unit Test Case Data

Fuel Cost Coefficients

| Unit i | a _i | b _i | c _i | P _{min} | P _{max} |
|--------|----------------|----------------|----------------|------------------|------------------|
| 1 | 561.0 | 7.92 | 0.001562 | 150.0 | 600.0 |
| 2 | 310.0 | 7.85 | 0.00194 | 100.0 | 400.0 |
| 3 | 78.0 | 7.97 | 0.00482 | 50.0 | 200.0 |

SO₂ Emission Coefficients

| Unit i | a _{SO₂} | b _{SO₂} | c _{SO₂} |
|--------|-----------------------------|-----------------------------|-----------------------------|
| 1 | 1.6103e-6 | 0.00816466 | 0.5783298 |
| 2 | 2.1999e-6 | 0.00891174 | 0.3515338 |
| 3 | 5.4658e-6 | 0.00903782 | 0.0884504 |

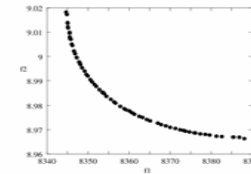
The system demand is 850 MW in all simulations. The system transmission loss is calculated by using a simplified loss expression:

$$P_{loss} = 0.00003 \cdot P_{G_1}^2 + 0.00009 \cdot P_{G_2}^2 + 0.00012 \cdot P_{G_3}^2$$

In all simulations, the population size was chosen as 100 individuals; crossover and mutation probabilities were 0.9 and 0.34 respectively. The distribution index for crossover and mutation were set at 10 and 20 respectively. The simulations were run for 10000 generations.

Simulation Results

Case 1: Without Wind



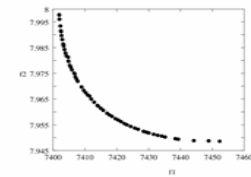
f1 = fuel cost (\$/hr)
f2 = SO₂ Emissions (ton/hr)

Best Compromise Solution

| | |
|-----------------------------------|----------|
| P ₁ (MW) | 490.551 |
| P ₂ (MW) | 262.923 |
| P ₃ (MW) | 111.463 |
| Cost (\$/hr) | 8356.358 |
| Emission SO ₂ (ton/hr) | 8.981 |

Case 2: With Wind

- In this case, wind penetration is assumed 12% (100 MW). Computer program was run with three thermal and one wind unit.



f1 = fuel cost (\$/hr)
f2 = SO₂ Emissions (ton/hr)

Best Compromise Solution

| | |
|-----------------------------------|----------|
| P ₁ (MW) | 441.110 |
| P ₂ (MW) | 224.064 |
| P ₃ (MW) | 96.294 |
| Cost (\$/hr) | 7414.994 |
| Emission SO ₂ (ton/hr) | 7.961 |

Conclusions

- It can be seen that in the case 2, efficient use of wind energy reduces the fuel cost and SO₂ emissions significantly.
- Simulation results show that algorithm is able to find a diverse Pareto-optimal front for the environmental/economic dispatch problem.
- The results show that the proposed approach is efficient for solving the multi-objective optimization where multiple Pareto-optimal solutions can be found in one simulation run.

Future Work

- To develop a general algorithm for multi-objective generation dispatch in power systems with hybrid energy resources
- This work will be extended with more objectives such as transmission limitations, stability and security of the system.