

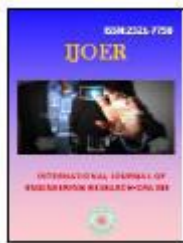


PARTICLE SWARM OPTIMIZATION BASED OPTIMAL POWER FLOW FOR COST MINIMIZATION OF AC POWER SYSTEMS

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ABSTRACT

Optimal Power Flow (OPF) determines an operating point that optimizes a selected objective while satisfying AC power-flow equations and operating limits. This paper documents the thesis-based PSO formulation and reported five-bus and IEEE 30-bus results, retaining the original numerical evidence while adding updated literature context.

Keywords—Optimal power flow; particle swarm optimization; economic dispatch; generation cost; penalty function; IEEE 30-bus; MATLAB; metaheuristic optimization.

1. Introduction

Optimal Power Flow (OPF) determines an operating point that optimizes a selected objective while satisfying AC power-flow equations and operating limits. The thesis describes fuel-cost minimization as the main objective and reviews gradient, linear, quadratic, Newton, interior-point and intelligent approaches [1]–[6]. The conventional OPF literature includes nonlinear/quadratic, Newton, linear-programming and interior-point approaches [2], [3].

Recent reviews show that OPF research has expanded toward renewable uncertainty, storage, multi-objective operation, hybrid metaheuristics and convex-relaxation approaches. A systematic review examined recent electric-power optimization papers and identified PSO, genetic algorithms and Differential Evolution among frequently used metaheuristics. A review covers the evolution from conventional methods to metaheuristic, machine-learning and convex-relaxation approaches [14], [18].

II. Problem Formulation

The fuel-cost objective is represented by a quadratic generator-cost function plus penalty terms:

$$F(P_G) = \sum_i (a_i P_{Gi}^2 + b_i P_{Gi} + c_i) + \text{PENALTY}$$

The AC active and reactive power-balance equations form equality constraints. The dependent variables include slack-bus active power, load-bus voltage, generator reactive power, and line loading; the control variables include generator active power, generator voltage, transformer taps, and shunt VAR compensation [5], [8].

Table I. OPF Constraint Conditions

Constraint	Condition
Active Power (P_G)	$P_{G,\min} \leq P_G \leq P_{G,\max}$
Reactive Power (Q_G)	$Q_{G,\min} \leq Q_G \leq Q_{G,\max}$
Voltage (V_L)	$V_{L,\min} \leq V_L \leq V_{L,\max}$
Line Loading (S_l)	$S_l \leq S_{l,\max}$

III. PSO Methodology

Each particle represents a candidate control vector.

Velocity is updated as:

$$v_{id}(t+1) = wv_{id}(t) + c_1r_1(pbest_{id} - x_{id}) + c_2r_2(gbest_d - x_{id})$$

followed by the position update:

$$x_{id}(t+1) = x_{id}(t) + v_{id}(t+1)$$

The source implementation evaluates power flow, cost, and penalties, updates $pbest/gbest$, and enforces limits.

The thesis uses standard PSO with inertia weight. For the five-bus case, the population is 100 and maximum iterations are 100,000; for the IEEE 30-bus system, the population is 10 and maximum iterations are 500. Parameters are set to $c_1 = c_2 = 2$, with inertia decreasing linearly from 0.9 to 0.4 [4]–[7]. The PSO formulation is consistent with established PSO-based OPF formulations reported in the literature [5], [8].

Table II. PSO Parameter Settings

Parameter	Five-Bus System	IEEE 30-Bus System
Population	100	10
Maximum iterations	100,000	500
c_1/c_2	2 / 2	2 / 2
Inertia (w)	0.9 $\rightarrow$ 0.4	0.9 $\rightarrow$ 0.4
Threshold	1×10^{-6}	1×10^{-6}

IV. Test Systems

- **Five-Bus System:** Contains three thermal generators at buses 1–3 and seven branches. Generator active-power limits are 10–85 MW, 10–80 MW, and 10–70 MW.
- **IEEE 30-Bus System:** Contains six generators at buses 1, 2, 5, 8, 11, and 13, and 41 branches. Four branches have off-nominal transformer ratios, and several buses contain shunt VAR compensation. Load-bus voltage limits are 0.95–1.10 pu.

V. Five-Bus Results

The reported PSO solution yields a cost of 1597.71 \$/h with a power loss of 2.3407 MW. The MATLAB global-best sequence falls from about 1649.22 \$/h at initialization to 1597.7185 \$/h at convergence.

Table III. Optimal Power Flow Results for the Five-Bus System (Gradient Method vs. PSO)

Quantity	Without (Gradient)	PSO	With PSO
P_1 (MW)	33.4701		33.09028
P_2 (MW)	64.0974		64.4269
P_3 (MW)	55.1011		54.8553
Cost (\$/h)	1599.98		1597.71
Loss (MW)	3.0524		2.3407

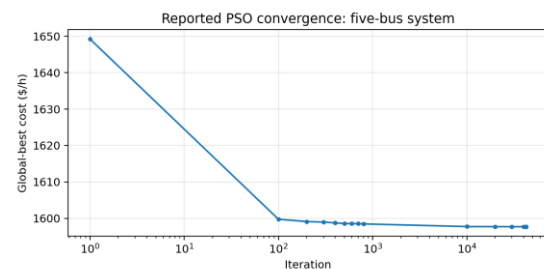


Fig. 1. Reported PSO convergence for the five-bus system.

VI. IEEE 30-Bus Results

The reported PSO generator outputs are 176.7327, 48.8339, 21.4524, 21.6692, 12.0886, and 12.0000 MW at buses 1, 2, 5, 8, 11, and 13, respectively. The reported cost is 801.8436 \$/h, and the thesis confirms compliance with the stated load-bus voltage limits.

Table IV. Cost Comparison of Metaheuristic Methods for the IEEE 30-Bus System

Method	Cost (\$/h)
GA	803.7075
DE	811.8780
ACO	803.1216
PSO	801.8436

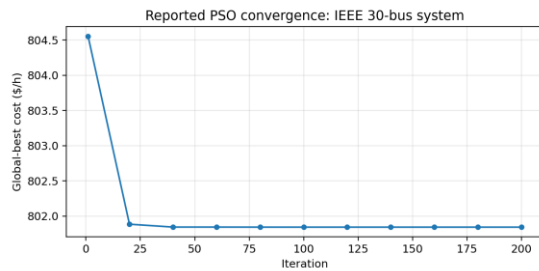


Fig. 2. Reported PSO convergence for IEEE 30-bus.

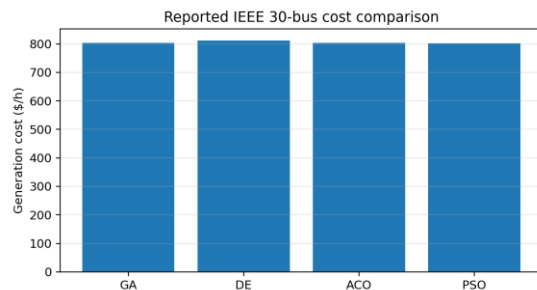


Fig. 3. Reported IEEE 30-bus cost comparison.

VII. Recent Literature and Discussion

Recent work includes adaptive constraint DE, TLSBO, modified ABC, MFO with renewable generation, FACTS-aware metaheuristic optimization, Coot optimization, advanced GWO, and multi-objective coyote optimization. These studies show a shift toward multi-objective and hybrid formulations rather than solely focusing on fuel-cost minimization [10]–[13], [15], [16], [19]. The TLBO-based OPF study provides an earlier benchmark for comparison with later metaheuristics [9].

Metaheuristic OPF also faces a computational-cost challenge because repeated load-flow calculations can dominate runtime. Recent research has proposed incremental and sensitivity-based approaches to reduce the frequency of full power-flow calculations [14].

VIII. Limitations and Conclusion

The numerical values are thesis-derived rather than newly rerun. The thesis fully documents the PSO settings and outputs, but the available text does not provide a complete common experimental protocol for GA, DE, and ACO. Therefore, the reported comparison serves as benchmark evidence rather than a universal ranking. Future

work should use identical implementations, multiple independent runs, execution-time measurements, and larger test networks [6].

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