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# Combined Differential Evolution Algorithm and Ant System for Optimal Reactive Power Dispatch

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**Abstract**

This paper proposes a hybrid approach to solve the optimal reactive power dispatch (ORPD) problem. Traditionally, ORPD is defined as the minimization of active power transmission losses by controlling a number of control variables, which is formulated as a nonlinear constrained optimization problem with continuous and discrete variables. Based on the original differential evolution (DE) algorithm, the proposed approach combines variable scaling mutation and probabilistic state transition rule used in the ant system to deal with the ORPD problem. To verify the performance of the proposed method, the similar evolution approaches such as the evolutionary programming (EP) and particle swarm optimization (PSO) are also implemented using the same study case. Testing on the IEEE 30-bus system indicates that the proposed approach can obtain better results with lower active power transmission losses and better convergence performance than the existing methods.



*Keywords:* optimal reactive power dispatch; differential evolution; ant system

## 1. Introduction

The ORPD is a subproblem of the optimal power flow (OPF) calculation and has a significant influence on secure and economic operation of power systems. Traditionally, ORPD is defined as the minimization of active power transmission losses by controlling the generator terminal voltages, transformer tap settings, and shunt capacitors/ reactors. The purpose of ORPD is to reduce active power transmission losses and improve voltage profile in the power systems. Since the control variables such as shunt capacitors/reactors and the tap settings of transformer have the discrete nature, the ORPD is then formulated as discrete and nonlinear optimization problem.

Much research has been devoted to cope with the ORPD problem. These techniques include the nonlinear programming method [1], mixed-integer programming method [2], interior point method [3],


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genetic algorithm [4], particle swarm optimization [5], and adaptive immune algorithm [6]. In general, the techniques mentioned above can serve as effective tools for solving the ORPD problem.

DE was first introduced by Storn and Price in 1995 [7]. It has the parallel search and rapid convergence naturals. In this paper, a hybrid approach combining variation of basic DE and ant system [8] has been proposed to solve the ORPD problem. Based on rapid convergence and global search ability, the proposed approach can offer higher probability of converging toward global solution than the other methods.

## 2. Problem Formulation

Typically, ORPD is to minimize active power transmission loss subject to a number of constraints. The objective of active power transmission loss can be expressed as follows.

$$f_Q = \sum_{k\in(i,j)} P_{l,k} = \sum_{i=1}^{L}\sum_{j=1}^{L}\left[g_{ij}\left(|V_i|^2 + |V_j|^2 - 2|V_i||V_j|\cos(\delta_i - \delta_j)\right)\right] \quad (1)$$

where $f_Q$ is the active power transmission loss, $P_{l,k}$ is the active power transmission loss of branch $k$, $L$ is the number of transmission lines, $|V_i|$ is the voltage magnitude at bus $i$, $g_{ij}$ is the conductance between bus $i$ and $j$, and $\delta_i$ is the voltage phase angle of bus $i$.

The objective in (1) must satisfy the following constraints.

- *Power balance constraint*. The injected active power at each bus must be equal to active power demand plus active power transmission loss at each bus, i.e. $P_{Bi} = P_{Di} + P_{li}$. Similarly, the reactive power balance constraint must be satisfied as well.
- *Reactive generation constraint*. The injected reactive power at each generation bus (PV bus) must be controlled within the lower and upper limits, i.e. $Q_{Bi,\min} \le Q_{Bi} \le Q_{Bi,\max}$.
- *Bus voltage constraint*. Each voltage magnitude of load bus (PQ bus) must be controlled within the lower and upper limits, i.e. $V_{i,\min} \le |V_i| \le V_{i,\max}$, in order to remain the stable operation of the power system.
- *Capacitor and transformer tap setting constraints*. The capacitor and transformer tap setting must be tuned within the lower and upper limits, i.e. $Q_{C,\min} \le Q_C \le Q_{C,\max}$ for capacitor and $T_{k,\min} \le T_k \le T_{k,\max}$ for transformer. In this paper, the capacitor and transformer tap setting are regarded as continuously adjustable variables.

## 3. The Proposed Approach

Based on the basic evolutionary strategies, the proposed approach achieves the fittest individual after repeated initialization, mutation, recombination, and selection operations as follows.

- Initialization

Let $p_i$=[$p_{i1}$, $p_{i2}$, …, $p_{iM}$] be a trial vector representing the $i$th individual ($i$ =1, 2, …, $P$) of the population to be evolved, where $P$ is the population size and $M$ is the dimension of each individual. The elements in vector $p_i$ represent the decision variables (genes) which are randomly generated as follows.

$$p_{ij} = p_{ij,\min} + \sigma \times (p_{ij,\max} - p_{ij,\min}),\ \ j = 1,\ 2,\ ...,\ M \quad (2)$$

where $p_{ij}$ represents the $j$th gene of the $i$th individual, $p_{ij,min}$ and $p_{ij,max}$ mean the lower and upper bounds of $p_{ij}$, respectively; and $\sigma$ represents the uniform random number between 0 and 1. In this paper, the trial