# Wind Driven Optimization Paradigm Using Lévy Flights Applied to Multiobjective Transformer Design

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**In recent years a new optimization metaheuristic algorithm was proposed called Wind Driven Optimization (WDO). WDO is a stochastic nature-inspired paradigm based on atmospheric motion. In this paper, a modified version of WDO is proposed and evaluated, based on Lévy flights to tune its control parameters, called Lévy WDO (LWDO). Lévy flight or anomalous diffusion process is a random walk characterized by Markov chain in which the step-lengths have a probability distribution that is heavy-tailed. To validate the multiobjective optimization performance of the WDO and the proposed LWDO, a benchmark for optimizing of a safety isolating transformer is adopted. In this paper, the transformer design optimization is treated as a multiobjective problem, with the aim to minimize both the total mass (iron and copper materials) and losses taking into consideration design constraints. Simulation results testify that the LWDO is a promising approach for multiobjective optimization as it outperforms the classical WDO.**

***Index Terms*—Optimization, Transformer design, Metaheuristics, Wind driven optimization.**

## I. Introduction

MULTIOBJECTIVE OPTIMIZATION involves the simultaneous optimization of competing objectives. In the absence of any preference information, a non-dominated set of solutions is obtained by multiobjective optimization, instead of a single optimal solution. These solutions called Pareto optimal solutions are optimal in the wider sense that no other solutions in the search space are superior to them when all objectives are considered.

In this paper, a multiobjective version and an improved approach of the wind driven optimization (WDO) [1] using Lévy flights (LWDO). The design of the WDO was inspired by earth's atmosphere where the wind flow participates of an attempt to balance horizontally the air pressure and it can be effective in solving multidimensional numerical optimization problems. However, the WDO as other population based algorithms can present premature convergence and stagnate at suboptimal solutions.

Transformer design optimization (TDO) can be viewed as a constrained multiobjective optimization problem (MOP). Examples of TDO can be viewed in [2]. A benchmark for optimizing of a safety isolating transformer is adopted to validate the optimization using the WDO and the proposed LWDO in multiobjetive versions. In this paper, the TDO is approached as a multiobjective problem, with the aim to minimize both the total mass ($f_1$) and the losses ($f_2$), taking into account the design constraints.

## II. Transformer Design Optimization Problem

As mentioned in [3], the TDO problem contains 7 discrete design variables. There are three parameters $\{a, b, c\}$ for the shape of the lamination, one for the frame $\{d\}$, two for the section of enamelled wires $\{S_1,S_2\}$, and one for the number of primary turn $\{n_1\}$. There are 24 types of lamination, 62 combinations between the laminations EI and the frames, and 62 types of enamelled wires. The number of primary turn $n_1$ is integer but only 1,000 values are allowed, leading to 246,078,000 possible combinations.

There are 6 inequality constraints applied on this problem. The copper and iron temperatures should be less than 120°C and 100°C, respectively. The magnetizing current $I_\mu/I_1$ and drop voltage $DV_2/V_2$ are less than 10%. Finally, the filling factor of both coils is lower than 0.5. The objective functions are to minimize the total mass $M_{tot}$ of iron and copper materials and the losses, i.e., maximize the efficiency ($\eta$).

## III. Description of the WDO and LWDO

In the following sub-sections, the procedures of the WDO and the LWDO are briefly described.

### A. The Classical WDO

The WDO algorithm uses the wind flow from earth's atmosphere as inspiration. The wind flow is generated due to the radiation of the sun over the surface and the heating emerged from that phenomena, which occurs irregularly, generating fluctuations of temperature that generates differences of density on the air [4]. This dynamic movement comes from the pressure gradient. The representation of the atmospheric motion in the WDO uses the Lagrangian mathematical representation due to its infinitesimal fluid parcels collection that can be governed by Newton's second law of motion.

In the case of wind flow, it is assumed that the atmosphere is a homogeneous fluid and that hydrostatic balance is present. Considering the Cartesian coordinate description and that the horizontal movement is stronger than the vertical movement the flow can be treated as horizontal motion only [5].

The process of the air parcel trajectory calculation starts from the Newton's second law of motion, which states that the total force applied on an air parcel causes its acceleration, the relationship between pressure and density, friction force, gravitational force and Coriolis force.

### B. The Proposed LWDO

In the classical WDO, there are multiple control parameters that must be chosen prior to starting an optimization using WDO, including the universal gas constant ($R$), the temperature ($T$), the gravitational constant ($g$), the friction coefficient ($\alpha$), and the Coriolis effect ($c$). The stability of the WDO performance against parameter settings is generally unknown.

In contrast, to improve the diversity of the multiobjective WDO the proposed LWDO approach uses Lévy flights [6] in order to tune all control parameters. A Lévy flight random walk pattern uses a Lévy probability distribution that has an infinite second moment, which is advantageous when targets are sparsely and randomly distributed. In the focus of this paper, the Lévy flight is adopted as the main diversity approach in order to obtain a better distribution of Pareto-optimal solutions.

### C. WDO and LWDO in Multiobjective Version

To deal with conflicting objectives, one should adapt the WDO and LWDO algorithms such that the goals in multiobjective optimization are attained. Namely, the solutions which approximate the true Pareto front are expected to be as close to its values and as diverse as possible, in such a way that at the end of the optimization procedure the designer has representative solutions to choose from.

To this end, the present work adopts the same truncation procedure based in non dominance and crowding distance as in [7]. Thus, at the end of each iteration, the set containing the solutions formed by the current and previous iterations are sorted according to (i) non dominance and (ii) crowding distance and then truncated such that the number of solutions for the next iteration is kept constant. The best individual at each iteration is chosen randomly in the 10% first sorted individuals according to the two aforementioned criteria, as in [8].

There are inequality constraints to the approached TDO problem. So, the WDO and LWDO multiobjective versions must be supplemented with a mechanism to efficiently handle constraints. In this paper, a third objective function $f_3$ to be minimized related to constraints-handling is adopted.

## IV. Optimization Results

Both WDO and LWDO algorithms were run 30 times with a population size of 100 and a stopping criterion of 50,000 function evaluations. The control parameters adopted for WDO were set according to [1], where $-2\Omega RT$ is equal to 0.4, $RT$ is equal to 3, $g$ is equal to 0.2, $\alpha$ is equal to 0.4 and maximum velocity is equal to 0.3.

Numerical results are shown in Table I (all feasible solutions, where $f_3 \leq 0$). The resulting algorithm exhibits promising performance in terms of the Pareto fronts (Table I) as shown in Fig. 1.

TABLE I
PERFORMANCE INDICES (30 RUNS)

| Indices | WDO | LWDO |
|---|---|---|
| Pareto front of feasible solutions * | 11 | 18 |
| Normalized Euclidian distance ($f_1$, $f_2$) * | 0.8736 | 0.6890 |
| **Total** Pareto solutions obtained in 30 runs | 154 | 192 |

* this index uses the data of the Pareto front **filtered** out of 30 runs

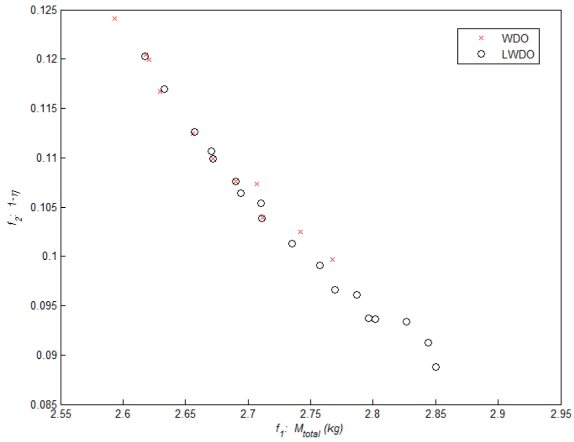


Fig. 1. Pareto set points (filtered of 30 runs) using WDO and LWDO.

In multiobjective optimization, the goal of the WDO or LWDO is to search a solution set of which the corresponding objective vectors are closely and evenly distributed on the Pareto front.

According to the results, the LWDO presented promising results in terms of the quality of the solutions found in the Pareto front. Furthermore, LWDO solution sets have better Pareto front convergence than WDO preserving solution set diversity.

## V. Concluding Remarks

The paper proposes multiobjective WDO and LWDO algorithms for TDO, which uses an external archiving scheme and the ranking with non dominance and crowding distance. The mentioned optimization algorithms have been successfully applied to the TDO problem.

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