Wind-Driven Optimization Methodology: The ideal power flow issue

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Abstract

Wind driven optimization Technique is one of the optimization method based on atmospheric motion, and it is global optimization modern nature inspired method. The technique is working on population based iterative heuristic global optimization algorithms for multi dimensional and multi model in the search domain to implement the constraints. In this paper, the Wind driven optimization Technique is used to solve optimal power flow problem. In order to show the effectiveness of the proposed method, it has been applied to the standard IEEE 30-bus for generation fuel cost objective that reflect the performances of the power system. Furthermore, the obtained results using the proposed technique have been compared to those obtained using other techniques reported in the literature. The obtained results and the comparison with other techniques indicate that the wind driven optimization technique provides effective and robust high quality solution when solving the optimal power flow problem with different complexities

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Introduction

As a fundamental tool for power system operation, the optimal power flow problem [1] is used. The fundamental objective of the optimal power flow problem is to optimize the power system while also satisfying operational restrictions in order to attain the ideal operating condition [2].

The optimal power flow problem has been studied by experts for the past 50 years. Numerous deterministic optimization strategies have been successfully used in the past. Newton-based strategies, gradient-based techniques, sequential quadratic programming, simplex techniques, and interior point techniques are a few of them. The most well-known conventional optimization techniques and methods that were applied to the OPF problem are listed in [3, 4]. Despite the fact that many of these optimization techniques are mostly applied in industrial settings and have high convergence properties, they nonetheless have significant drawbacks. Among their drawbacks are their inability to ensure global optimality, difficulty to deal with binary or integer variables, and the fact that they were created using theoretical premises that may not be suitable for optimal power flow situations.

A significant amount of "Heuristic" non-deterministic research has been prompted by the recent rapid improvements in computational intelligence technologies. which is based on atmospheric motion, is one of the most recent innovations in optimization techniques. It is also a global optimization technique that was influenced by modern nature. It has been demonstrated that the wind optimization technique works well in multidimensional numerical optimization situations.Using the WDO technique to address the OPF problem is the paper's major goal. Under the aim function of minimising the cost of generation fuel, the WDO technique's performance is sought after and evaluated on the IEEE-30 bus test standard.

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Optimum Power Transfer

The mathematical problem with non-linear constraints can be stated as follows.

$$\text{Minimize } f(x,u) \quad (1)$$

Subject to $g(x,u)=0$ (2) $h(x,u)\le 0$

(3)

The quantity for the objective function.

1) The target fuel price

In order to meet the existing load on a particular system, the real power supplied by the power plants' producing units should be distributed optimally and in the most cost-effective manner possible. A potential simplified quadratic cost expression for each unit of actual power output subject to different constraints is [7]. The fuel cost-coefficients for the generators are where? The total cost of gasoline for all units can be calculated mathematically as (5), but in order to minimize the goal, it must also satisfy the following equality and inequality conditions.. These restrictions can be stated as

I Restrictions on equality

These restrictions are merely load flow equations that have been computed and satisfied using the traditional load flow method. The load flow expressions for the active and reactive power balance can be presented. a

$$p_{Gi} - p_{Di} = \sum_{j=1}^{N_{bus}} |V_i||V_j||Y_{ij}|\cos(\theta_{ij} + \delta_j - \delta_i) \quad (6)$$

$$Q_{Gi} - Q_{Di} = \sum_{j=1}^{N_{bus}} |V_i||V_j||Y_{ij}|\sin(\theta_{ij} + \delta_j - \delta_i) \quad (7)$$

(ii). Constraints on inequality

a generator's restrictions Voltage, active, and reactive outputs for all generators, including the slack, should be constrained by their lower and upper limitations in the manner described below:

Security constraints

These include restrictions on the voltage's strength at bus and transmission line loadings. To remain within its lower and upper functioning limits, the voltage of each load bus must be restricted. Eqn (1) as follows:

$$J_{aug}(x,u) = J(x,u) + R_p\left(P_{G_1} - P_{G_1}^{limit}\right)^2 + R_v \sum_{m=1}^{NL}\left(V_m - V_m^{limit}\right)^2 + R_q \sum_{m=1}^{NG}\left(Q_{G_m} - Q_{G_m}^{limit}\right)^2 + R_s \sum_{m=1}^{nl}\left(S_{l_m} - S_{l_m}^{max}\right)^2$$

(8)

where, $R_p, R_v, R_q,$ and R_s are the penalty factors related to the constraints. The limits values can be considered as

$$x^{limit} = \begin{cases} x^{max}; & x > x^{max} \\ x^{min}; & x < x^{min} \end{cases}$$

Where, 'x' is the value of P_{G_1}, V_m and Q_{G_m}

Method of optimization driven by the wind:WDO is a method of global optimization based on air motion and inspired by natural phenomena. It has been shown that WDO is both easy to use and effective at solving multidimensional numerical optimization problems. The method employs population-based iterative global optimization algorithms for multidimensional and multimodel search domains to implement the restrictions. This is how INDO is related to other nature-inspired optimization methods, where population-based heuristic iterative processes can be identified for dealing with the multi-dimensional optimization issues. The use of terms like gravitation and coriolis forces in the velocity update equations, in contrast to similar fundamental techniques, provides the fine tuning with an extra degree of flexibility and resilience. The operation can be explained via a flowchart.

Theoretical foundation and driving force of WDO

$$P = \rho RT \quad (10)$$

where, P is the pressure, R is the universal gas constant and T is the temperature.

The wind is affected by four main factors in Eq. (9), which either direct the wind in a certain direction or deflect it off its course. The friction force () only opposes this motion as shown in Eq., whereas the pressure gradient force () is the most observable force moving the air (14). whereas when it is transferred to N-dimensional space, the gravitational force () behaves as a vertical force in a three-dimensional atmosphere. The Coriolis force, which shifts the direction of wind from one dimension to another, is brought on by the earth's rotation. It is implemented in WDO as a movement in one dimension that influences a change in velocity in another (Bayraktar et al., 2010).

The physical equations that govern each of these forces are given below:

$$\vec{F}_{PG} = -\nabla \rho \delta V \quad (11)$$

$$\vec{F}_{G} = \rho \delta V \vec{g} \quad (12)$$

$$\vec{F}_{C} = -2\Omega \times \vec{u} \quad (13)$$

$$\vec{F}_{F} = -\rho \alpha \vec{u} \quad (14)$$

Where, $\nabla \rho$ is the pressure gradient, δV represents an infinitesimal air volume,Ω represents rotation of the earth, g is the gravitational acceleration, and u is the velocity vector of the wind.

The summation of all four forces can be obtained by (15):

$$\rho \vec{u} \Delta t = (\rho \delta V \vec{g}) + (-\nabla P \delta V) + (-\rho \alpha \vec{u}) + (-2\Omega \times \vec{u})$$

The velocity update equation can be computed by using an infinitesimal air parcel that is travelling with the wind (16). In order to simplify things, a unity time step (t = 1) might be assumed when writing the ideal gas law equation from equation (10). Equation for the velocity update is:

(15)

$$\vec{u}_{new} = ((1-\alpha)\vec{u}_{old}) + g(-\vec{x}_{old}) + \left[\left|\frac{P_{\max}}{P_{old}} - 1\right| RT(x_{\max} - x_{old})\right] + \left[\frac{-C u_{old}^{other\,dim}}{P_{old}}\right] \quad (16)$$

According to Eq. (16), updated velocity (uold), air parcel location (xold), distance from the highest pressure point discovered (xmax), maximum pressure (Pmax), pressure at the current location (Pold), temperature (T), gravitational acceleration (g), and constants R,, and c all affect updated velocity (unew) for the following iteration.

The pressure term in WDO expression (16) is comparable to a chromosome's fitness in terms of genetic analysis. Similar velocity update equations can be realised by comparing WDO and PSO. Equation (16) can be used to update the air parcel's position after updating its velocity.

$$\vec{x}_{new} = \vec{x}_{old} + (\vec{u}_{new} \times \Delta t)$$

According to Eq. (17), the air parcel would encounter some friction-induced resistance as it followed its prior path. is a gravitational force that pushes away from the coordinate system's centre. Assumed to be the world's best location for the optimization issue, t denotes the force acting against the position of maximum pressure. follows the deflecting Coriolis force, in actuality. This is how WDO provides a straightforward yet incredibly powerful approach to handling challenging optimization issues. WDO restricts the movement of air parcels to the range [-1, 1] for each dimension. Various boundary conditions have been predicted for particle-based optimization in the literature[11], however in the case of WDO, if an air parcel tries to cross one of these boundaries in any dimension, its location in that particular dimension is set to the boundary value.

Every air parcel that is confined at the boundary eventually drifts back into the search space due to the gravitational pull. Additionally, it should be examined that the updated air parcel velocities are limited to a maximum value every iteration. This is done to prevent air shipments from making large movements and of the search area. According to Eq. (18), once the velocity magnitude exceeds the specialised maximum in any dimension, the velocity in that dimension is constrained.

$$u_{new}^{*} = \begin{cases} u_{\max} & if \quad u_{new} > u_{\max} \\ -u_{\max} & if \quad u_{new} < -u_{\max} \end{cases} \quad (18)$$

where, the direction of motion is preserved but the magnitude is limited to be not more than [umax] at any dimension, and [u*max] represents the adjusted velocity after it is limited to maximum speed.

Application and results

It has been tested on an IEEE 30-bus test system to demonstrate the efficacy of the proposed WDO approach. In the MATLAB computing environment, the developed software was written.

The characteristics of the IEEE 30-bus test system are as follows: Buses 1, 2, 5, 8, 11, and 13 are served by six generators, whereas lines 6-9, 6-10, 4-12, and buses 10, 12, 15, 17, 20, 21, 23, 24 and 29 are served by nine shunt VAR compensation buses [12, 13].

[14] provides the line, bus, generator, and minimum and maximum values for the control variables. The OPF problem for the objective function of generation fuel cost has been solved using the suggested method.

The suggested method has been tested for OPF, and Table 1 lists the best settings that were found. Compared to the initial scenario, it appears that the cost of fuel generation overall has significantly

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decreased (Normal load flow). Quantitatively, it is decreased from 901.951 USD per hour to 799.069 USD per hour, an 11.39% percent cost reduction.

The findings achieved using the WDO technique given in this research are compared to some other techniques reported in the literature under the identical conditions, i.e. control variables limitations, restrictions, and system data, as shown in Tables 2. The results 799.0691 achieved using TLBO are either superior or comparable to those obtained using other strategies, which suggests that the suggested technique outperforms numerous techniques used to solve various OPF issues. This demonstrates its capacity to identify higher-quality solutions.

Conclusion

The wind-driven optimization strategy that we have devised and presented in this study is a novel approach to the OPF problem in power systems. It is a cutting-edge, atmospheric motion-based global optimization technique. The IEEE 30-bus, where objective function has been taken into consideration for the minimization of generation fuel cost, has successfully and effectively adopted and deployed WDO. The following reasons, among others, make this paper important: 1) The high ranking of the suggested technique when compared to other techniques, which has been demonstrated, and 2) The effectiveness of the WDO, which has been demonstrated by conducting a statistical analysis that has demonstrated its strength by converging on the optimum value or very close to it every time.

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