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Improved Wind Driven Optimization Algorithm for Solving Optimal Power Flow Problem Considering Renewable Energy Sources.

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ABSTRACT:

The electric power system, which is an essential component of any developing economy, is an unpredictable element that must be constantly monitored. System parameters must be kept at predetermined levels or the power system authority will suffer financial and structural losses. The Optimal Power Flow (OPF) method is the best way to evaluate these parameters before doing power system corrections. There is also a need to reduce the cost of power system operation. The goal of this research was to carry out the optimal flow as well as the economic load dispatch. The MATLAB program served as the setting in which the optimization took place. The technique for Improved Wind Driven Optimization was used on the IEEE-30 bus system with wind and solar power incorporated to carry out the Optimal Power Flow, Economic and load dispatch. The method chosen implemented on the Nigerian Power System. The Improved Wind Driven optimization algorithm and wind driven optimization techniques were both used in carrying out comparison analyses to ascertain which has a higher convergence rate. From simulations, it was observed that the IWDO was 0.499% fuel cost effective and 0.878% power loss effective than the WDO. Upon applying the IWDO on the IEEE-30 bus system, there was a 61.25% reduction in active power loss, 57.02% reduction in reactive power loss and 11.80% reduction in fuel cost.

KEYWORDS: wind driven, optimization, convergence, power flow and losses.

1. Introduction

The Optimal power flow (OPF) was formulated by Carpenter in 1962 [1]. Since then several techniques have been proposed for solving optimal power flow problems. The OPF is usually employed to optimize the cost of generation, reducing emissions, minimizing power loss along the transmission lines and ensuring that the voltage remains within stable limits. In carrying out this optimization process, the technical constraints of the power system must be satisfied. Ignoring these constraints can present challenging situations especially in large power systems. Thus, special care must be taken to ensure that these constraints are not violated. To understand OPF, let's think about an electrical grid like a transportation network. Just like cars need fuel to move, power systems require electricity to operate. OPF helps reduce operating costs, reduce power losses, improve system stability, and enable the integration of renewable energy sources [2]. OPF plays a crucial role in the electrical grid management and decision making processes, ensuring a reliable and sustainable supply of electricity to consumers [3]. Traditional techniques of resolving OPFs only use traditional sources that burn fossil fuels. With the increased penetration of renewable energy sources (RES) in the power system, it has become necessary to incorporate the uncertain character of these sources into the OPF problem due to challenges during the planning and operational phases. Many traditional ways for overcoming this problem have been presented since the inception of OPF [4].

The formulation of the optimal power flow problem is critical for planning and operating of electrical power networks. The power flow problem and the economic load dispatch (ELD) problem are two critical challenges in power systems that must be solved. The power flow embodies the generation, transmission network, and loads, whereas the fundamental goal of the economic load dispatch problem is to reduce generation costs while fulfilling power demand. The optimal power flow is a hybrid of power flow and economic load dispatch. As a result, the OPF is critical for the harmless and profitable operation of the electrical power system by appropriately setting control parameters such as voltages, active power of generator buses, transformer tap settings, and so on. The OPF's main goal is to improve (minimize or maximize) a certain target (cost, voltage stability, power loss, etc.) while meeting equality, inequality, and security requirements. The equality constraints include the power balancing equation, whereas the inequality constraints include voltage, maximum and minimum reactive and real power restrictions, and transmission line capacity, [5]

The desire to lower gas emissions, lower fuel costs, and boost efficiency has led to an increase in the usage of Renewable Energy Sources (RES) in the electrical power system. The electricity market is directly impacted by RES like wind and solar systems, which also reduce line losses, the cost of generating energy, and increase the stability and reliability of the power system [6].

Additionally, the effectiveness of power network control and operation is significantly impacted by the location of the RES in the grid. The duty of appropriately sizing and positioning the RES at an appropriate location on the electricity system falls on the network operators as a result. They are also in charge of efficiently managing RES and conventional power generation. Using RES and a variety of operational limitations, power loss, fuel cost, and voltage deviation issues in the power system can be transformed into an Optimal Power Flow (OPF) problem, [8].

1.1 Concept of Wind Driven Optimization Algorithm

A global optimization technique based on atmospheric motion is called the wind driven optimization (WDO) algorithm. Zikri Bayraktar created it at Pennsylvania State University [9 10]. The WDO is a population-based iterative heuristic global optimization technique with the ability to apply constraints on the search domain for multi-dimensional and multi-modal issues. Fundamentally, a population of infinitely tiny particles moves through an N-dimensional search space in accordance with Newton's second rule of motion, which describes how air molecules move through the earth's atmosphere [11, 12, 13] . When compared to previous particle-based techniques, WDO uses more terms in the velocity update equation, giving the optimization more robustness and degrees of freedom. Based on the idea that wind moves from high-pressure locations to low-pressure areas until there is pressure equilibrium, the wind-driven optimization method was created [14, 15]. Equation (1) illustrates how the WDO is formed as a foundation for the second law of Newton.

$$\rho\vec{\omega} = \sum\overrightarrow{Fi} \qquad \dots \qquad (1)$$

Where

ρ: Air density

F_i: Sum of all forces acting on the air particle

$\vec{\omega}$: Acceleration

1.2 PROBLEM FORMULATION

The thermal power generators run on fossil fuel, preferably natural gas because of its capacity to emit little carbon dioxide. Equation (9) outlines the link between the output power produced and the cost of fuel.

$$C_T(P_{TG}) = \sum_{i=1}^{NT} a_i + b_i P_{TG,i} + c_i\, P_{TG,i}^2 \qquad \dots \qquad (2)$$

Where

C_T: Total fuel cost

P_{TG}: Output power of thermal generator

$a_i, b_i\ and\ c_i$: Cost coefficients of the ith generator

NT: Total number of thermal power generators

$P_{TG,i}^{Min}$: Minimum power of the ith generator

1.3 Cost of wind and solar photovoltaic power

The direct cost of wind power plants in terms of scheduled power is given by Equation (10)

$$C_{W_{d,j}}\left(P_{W_{s,j}}\right) = d_{w,j} P_{W_{s,j}} \qquad \dots (3)$$

Where

$C_{W_{d,j}}$: Cost of wind power generation

$d_{w,j}\ and\ P_{W_{s,j}}$: Direct cost coefficient and scheduled wind power j-th wind power generator

The direct cost of the k-th solar power plant is given by Equation (11)

$$C_{S_{d,k}}\left(P_{S_{s,k}}\right) = d_{s,k} P_{s_{s,k}} \qquad \dots (4)$$

Where

$C_{S_{d,k}}$: Cost of solar power generation

$d_{s,k}\ and\ P_{s_{s,k}}$: Direct cost coefficients and scheduled solar power from k-th solar power generator

2.0 MATERIALS AND METHOD

This section outlines the materials needed to carry out the best power flow optimization in order reduce line losses, and enhance voltage profile while also minimizing the incremental fuel cost. The resources used in this research project are;

- Personal computer

The personal computer used for carrying out the work is SAMSUNG 535RC with the following specifications.

i. Intel(R) DUAL CORE CPU B800 @ 2.00GHz

ii. 2.00GHz x64-bit based processor;

iii. 64-bit Operating System (O.S);

iv. 2.00GB installed memory (RAM).

- MATLAB R2018a software
- Internet
- The IEEE-30 bus system
- The Nigerian Bus network

2.1 Methods

The IEEE-30 bus system and then the Nigerian power system with integrated renewable energy both used the improved wind driven optimization algorithm to run the best possible power flow. The implementation of OPF will take the following steps;

- Data was collected on the IEEE-30 bus system network
- Data was equally collected on the Nigerian power system
- The improved wind driven optimization algorithm was applied on the IEEE_30 bus system.
- The wind driven optimization algorithm also was applied on the IEEE_30 bus system.
- The results gotten from both algorithms were compared to see which is optimal.
- The Improved wind driven optimization was applied on the Nigerian power system incorporating wind power plants and solar power plants as renewable energy resources.

The chart presented in Figure 5 is a pictorial representation of the methodology to be followed in the research process;

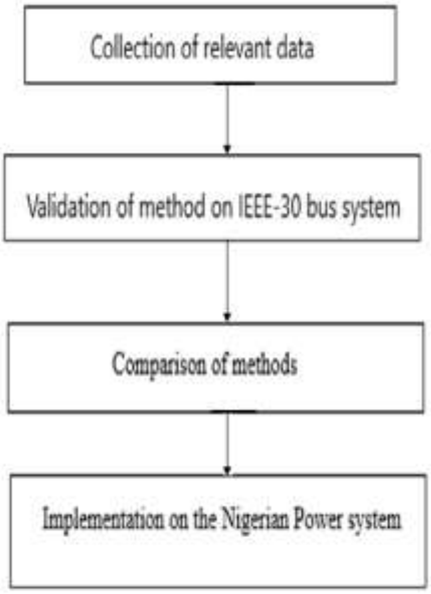

Figure 5: Flow of the methodology

3.0 RESULTS ABD DISCUSSION

3.1 The standard IEEE 33-Bus radial distribution system

The IEEE-30bus system was used as the test bed for the validation of this research work. The base case was first evaluated, then both the WDO and IWDO were introduced on the IEEE-30bus network so as to ascertain the performances of the said meta-heuristic techniques. Subsequently, the two techniques were compared. Finally, the optimal method was the implemented on the Nigerian power system so as to minimize, power loss, voltage loss and fuel cost.

3.2 Validation

Table 1: Performance evaluation on the IEEE-30 network

PARAMETERS	BASE CASE	WDO	IWDO
DG position and size (MW)	-	5(75) 23(43)	5(75) 28(18)
DG position and size (MVar)	-	5(1) 23 (1)	5 (1) 28 (1)
Total Ploss (MW)	18.902	7.4511	7.3240
Ploss reduction (%)	-	60.58	61.25
Total Qloss (MVAr)	73.495	31.866	31.587
Qloss reduction	-	56.64	57.02
Fuel cost ($/hr)	905.525	802.6178	798.7179
Cost reduction (%)	-	11.37	11.80
Computational time (sec)	1.525	228	230

Comparing the two convergences from figure 8 below, it can be observed that; the IWDO converged at the 14th iteration while for the WDO convergence occurred at the 16th iteration, thus giving the IWDO an upper hand as shown below.

Figure 1 below shows the convergence characteristics of both the WDO and IWDO combine together.

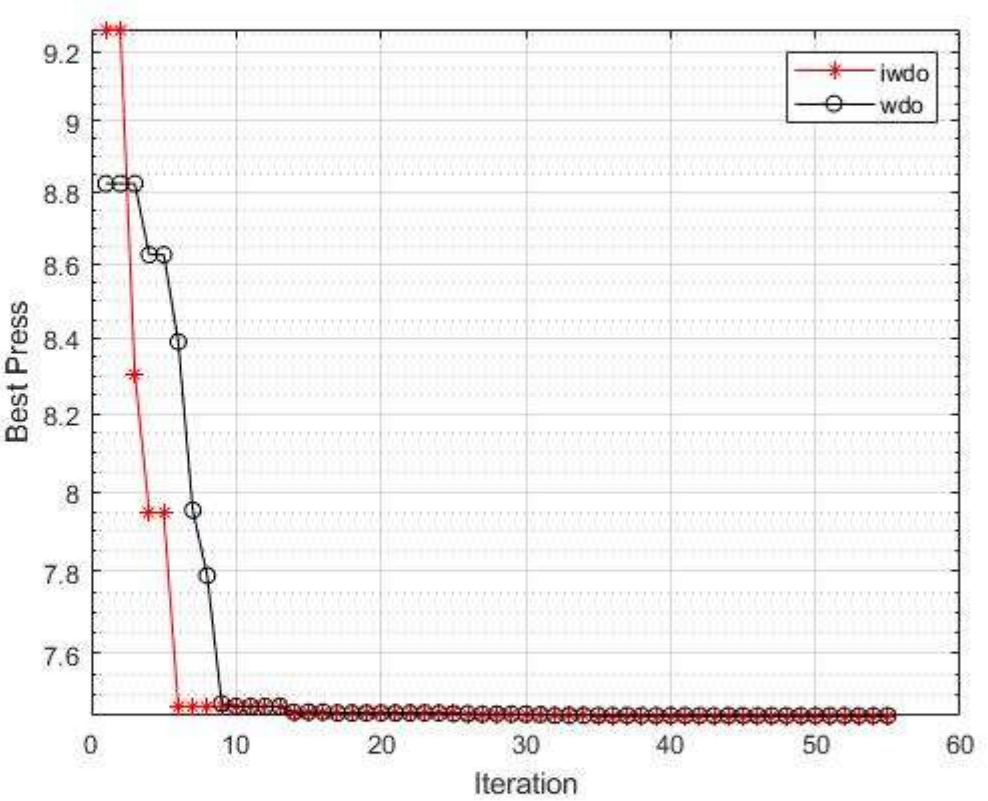

Figure 1: Combined Convergence graph for WDO and IWDO

Comparing the two convergence graphs on figure 1, it can be observed that; the IWDO converged starts showing faster convergence behaviour than the WDO and finally converges faster thus giving the IWDO an upper hand.

3.3 Nigerian power system

After testing and validating the Improved Wind Driven Optimization Algorithm on the IEEE-30 bus system, it was applied on the Nigerian power system as seen from Table 2.

Table 2: Implementation of WDO and IWDO on the Nigerian Power system.

Parameters	**Base Case**	**WDO**	**IWDO**
DG Position & Size (MW)	-	35(200) 38(51)	42(200) 23(30)
DG Position & Size (MVAr)		35(10) 38(74)	42(10) 23(36)
Total PLoss (MW)	22.703	19.418	16.756
PLoss Reduction (%)		14.47	26.19
Total QLoss (MVAr)	16.92	15.51	14.614
QLoss Reduction (%)	-	8.33	13.62
Fuel Cost (N/hr)	N 388.523	N 290.0738	N 267.582
Computational Time (s)	1.525s	239s	340s

Table 2 above contains three columns for the; base case, WDO and IWDO. From the table, the IWDO requires lesser active and reactive power compensation than the WDO as seen in row (1) and (2), hence it is less costly when carrying out the OPF using the IWDO. Furthermore, fuel cost was greatly minimized from 290.1N/hr to 267.6N/hr.

Figure 2 below represents the real power loss for the base case, WDO and the IWDO for the Nigeria network.

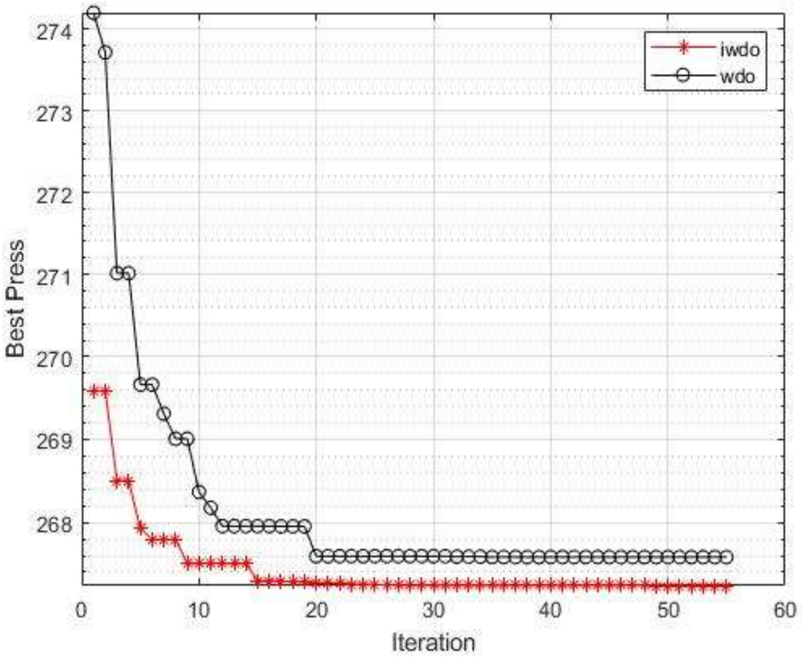

Figure 2: Combined Convergence graph for WDO and IWDO

Comparing the two convergence in figure 2, it can be observed that; the IWDO converged starts showing faster convergence behavior than the WDO and finally converges faster thus giving the IWDO an upper hand.

4.0 Conclusion

The IWDO algorithm was successfully tested and validated on the IEEE-30 bus network as yielded optimal results minimizing active power loss, reactive power loss and fuel cost.

i. A 61.25% loss of active power reduction was achieved after optimally placing and sizing the DG.

ii. A percentage reduction in reactive power loss of 57.02 was achieved upon placing the DG optimally.

iii. The cost of running the power system in terms of fuel (which is the principal running cost of any power system) witnessed a significant reduction from 905.53 $/hr to 798.72 $/hr thus a percentage gain in fuel cost of 11.80%.

The WDO and IWDO were compare to test for the best alternative and the following conclusions were brought about;

i. The Improved Wind Driven Optimization Algorithm was 0.499% better than the WDO in terms of minimizing fuel cost.

ii. The IWDO performed 0.876% better than the WDO in terms of minimizing power loss.

Hence, applying the IWDO on the Nigerian power system with renewable DGs at optimal positions will go a long way to minimize both technical and financial losses.

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