

# Application of Grey Wolf Optimization Algorithm for Improving Inertia Constant Selection in Wind Farm Deployments

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**Abstract**—This paper presents a Grey Wolf Optimization (GWO) algorithm for doubly fed induction generator (DFIG)-based wind turbine generators. In order to address the system operability challenges that have arisen as a result of the continuous reduction of system inertia caused by the increasing penetration of renewable power generation. The GWO algorithm that has been makes it possible for individual DFIG generators to contribute an efficient inertial response. This response helps to stabilize the rate at which the frequency is changing and minimizes the large frequency deviations, when disturbance occurs. The DC voltage of the DFIG runs at different levels in accordance with the changes in the inertia constant to facilitate energy exchange with the associated ac grid. Additionally, the standard control system for the DFIG has been updated to accommodate the implementation of the GWO algorithm. The proposed model utilized GWO in order to evaluate optimum values of inertia constant, that assists in improving output power efficiency levels. Concerning the DFIG, practical challenges such as maximizing active power while minimizing reactive power are examined, and pertinent solutions are offered for a variety of different cases.

**Index Terms**— Grey Wolf Optimization, Power System, DFIG, Wind, Inertia, Load Frequency Control.

## I. INTRODUCTION

In contrast to fixed-speed machines where active and reactive power control is not independent, DFIG-based wind turbines are the preferred option for network operators [1]. The turning speeds of conventional wind turbines are fixed; on the other hand, DFIG technology enables wind turbines to function at a broad range of speeds. Traditional wind turbines have fixed turning speeds. The back-to-back converter is affixed to the rotor of the DFIG, and its function is to provide the rotor with currents of varying frequencies in order to obtain the required rotational speeds of the rotor. This application note provides a demonstration of how a back-to-back converter controller may be used in combination with a DFIG wind turbine to generate electricity levels [2]. The dynamic response of DFIG to fluctuations in wind speed as well as the process of turbine braking. The amount of power that the wind has in the form of kinetic energy [3, 4], which is represented by the symbol  $P_v$ , by utilizing (1).

$$P_v = \frac{1}{2} \rho \pi R^2 V_v^3 \quad (1)$$

where  $V_v$  represents average speed of wind in the area,  $A = \pi R^2$ , where  $R$  represents rotor blade diameter, and  $\rho$  represents density of air in the current area sets. The power recovered by wind turbine can be represented via (2),

$$P_t = \frac{1}{2} \rho \pi R^2 V_v^3 C_p \quad (2)$$

The power coefficient  $C_p$  is a number that does not have a specific unit of measurement, and it is used to express how well a wind turbine is able to transform the kinetic energy of the wind into the mechanical energy that may be used. The power output of the wind turbine is what is used to measure the efficiency of the wind turbine. This coefficient shifts as a function of the wind speed, the speed of the rotor blades, and the angle at which the pitch is set [5, 6]. The length of the rotor blades in proposed model of a Wind Turbine with DFIG is set to  $R = 50$  meters, and the air density is set to  $= 1.225$  kilograms per cubic meter. Both of these settings are in meters per second squared. Automatic adjustment in pitch angle ( $\beta$ ) is done in such a way as to guarantee that the change in  $C_p$  as shown in the “Fig. 1”. The value of  $C_p$  will be maximum when  $\beta$  is taken to be zero. Apart from this, the output power of the turbine will be less if the value of  $\beta$  is different [16].

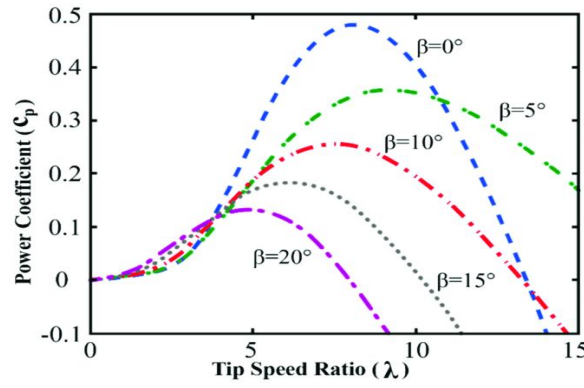


Figure 1. Power coefficient ( $C_p$ ) as a function of wind speed [16]

One of many DFIG controls may be activated at any one time, and the one that is used is determined by the zone in which the machine is now running. After investigating performance of different models [7, 8, 9] it can be observed that existing models showcase high efficiency for control of DFIG operations. In this regard, it is feasible to observe that the models [10, 11, 12] that are now in use are either very sophisticated or do not incorporate a significant amount of control with the intention of maintaining constant output levels. In order to address these problems, one possible solution is described in Section 3, and it is titled "Design of a Machine Learning technique for increasing Inertia constant Selection in Wind Farm installations." The proposed model was put through an examination in section 4, during which its results were compared with those of previously executed DFIG-based deployments. This paper comes to a conclusion with a number of in-depth observations on the model that has been provided, as well as suggestions for optimization models that may enhance the performance of the model in a variety of use scenarios.

## II. PROPOSED GWO ALGORITHM FOR IMPROVING INERTIA CONSTANT SELECTION IN WIND FARM DEPLOYMENT

After referring existing DFIG based control models [13, 14, 15], it was observed that existing models do not use stochastic optimizations, which limits their applicability under real-time use cases. To overcome this limitation, proposed Grey Wolf Optimization (GWO) algorithm for estimation of inertia constant for DFIG based wind turbines is discussed in this text. The algorithm works via the following process,

- Initialize the following parameters,
  - Total wolves existing in the model ( $N_w$ )
  - Total iterations for which the model will be evaluated ( $N_i$ )
  - Learning rate for the model ( $L_r$ )
- Initialize all wolves to be 'Delta', and evaluate them for each iteration via the following process,
  - If the Wolf is currently marked as 'Delta', then process it, else go to the next wolf in sequence
  - To process a Wolf, generate its internal configuration via the following process,
- Stochastically generate an inertial constant via (3),

$$H_s = \text{STOCH}(0,1) \quad (3)$$

Where,  $H_s$  represents the inertial constant, and STOCH indicates a stochastic process to generate numbers between given ranges.

- Based on this value of  $H_s$ , simulate the model, and estimate its fitness via (4)

$$f = \frac{P_{\text{active}}}{P_{\text{reactive}}} \quad (4)$$

Where,  $P_{\text{active}}$  represents active power at the output of model, while  $P_{\text{reactive}}$  represents output reactive power levels.

- Evaluate fitness for all Wolves, and then estimate fitness threshold via (5)

$$f_{th} = \sum_{i=1}^{N_w} f_i * \frac{L_r}{N_w} \quad (5)$$

- At the end of each iteration, re-evaluate all Wolves via the following process shown in “Fig. 2”,

- Mark Wolf as ‘Alpha’, if  $f > 2 * f_{th}$  (6)

- Mark Wolf as ‘Beta’, if  $f > f_{th}$  (7)

- Mark Wolf as ‘Gamma’, if  $f > L_W * f_{th}$  (8)

- Else, Mark Wolf as ‘Delta’, if for this configuration,  $f < f_{th}$  (9)

Repeat this process for all iterations, and then select the ‘Alpha’ Wolf with maximum fitness levels. Due to selection of Wolf with maximum fitness, active power is increased, while reactive power levels are reduced at the output, which assists in improving circuit efficiency levels. This is advantageous, because it's possible that an excessive quantity of reactive power may cause the components to overheat, which would significantly cut down on the equipment's lifetime.

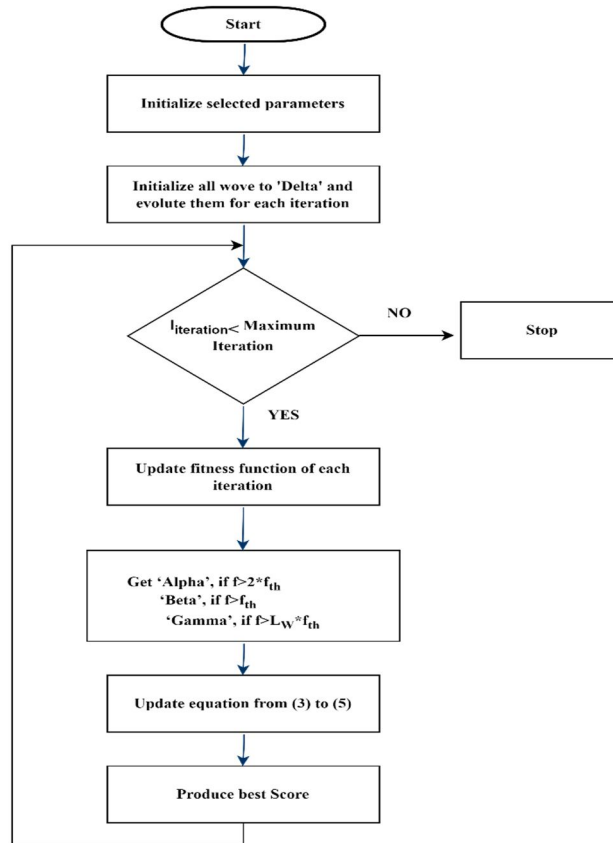


Figure 2. Flowchart of grey wolf

If power quality standards and regulations are not followed to, it may result in unanticipated shutdowns, power losses, and even fines. This is in addition to the fact that it may cause blackouts. Thus, the efficiency of DFIG based wind systems is improved due to selection of proper inertia constants. This efficiency is evaluated for different models in the next section of this text.

### III. RESULT ANALYSIS & COMPARISON

The proposed model uses GWO algorithm in order to evaluate optimum values of inertia constant, that assists in improving output power efficiency levels. To validate this performance, the model was evaluated on a standard DFIG model that can be observed from “Fig.3”, where a 120 kV source with 2500 MVA 3 Phase coupling device is connected to a 30 km line which is capable of feeding a 25 kV load via grounding transformer sets. The model uses 150 Ohms input source resistances with 50 Ohms load resistors. It also uses a combination of Wind Turbine with Drive Train in order to produce power base for generators, that drives an asynchronous machine for on load conditions. The circuit is capable of being driven by a 9 MW Wind farm that consists of 6 generator units, each having a capacity of 1.5 MW under real time loads.

The model is validated via modifying the inertia constants under different loads, and power efficiency was evaluated through (10).

$$\eta_{eff} = \frac{1}{N} \sum_{i=1}^N \frac{P(Out)}{R(Out)} \quad (10)$$

Where, P(Out) & R(Out) represents active and reactive power outputs for N different circuit reading iterations. designations.

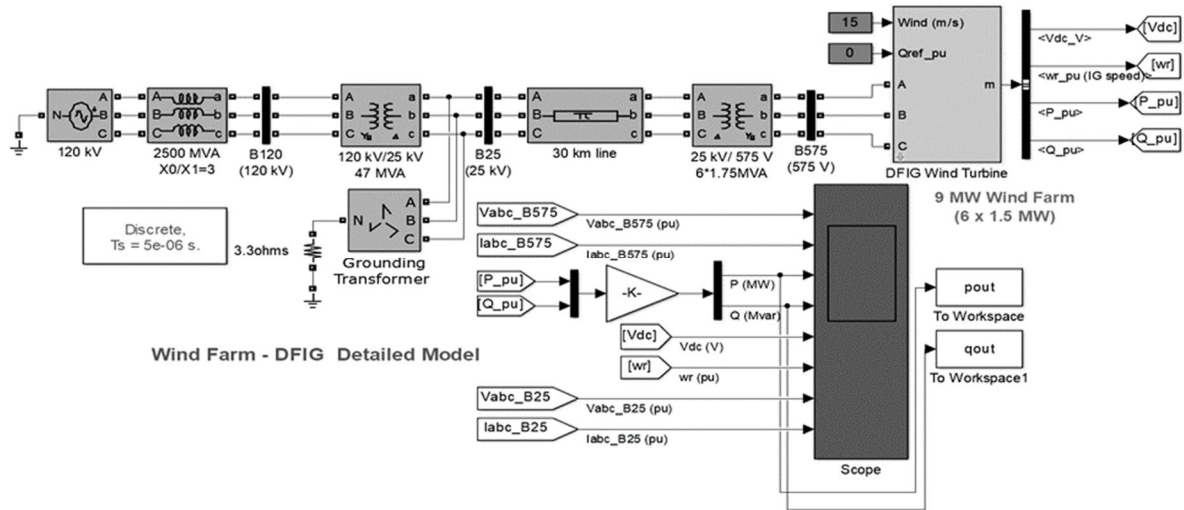


Figure 3. Simulink model of the DFIG model under different condition

The outputs were obtained for 3 Phase Voltage across 575V grid (Vabc\_575), 3 Phase Current across 575V grid (Iabc\_575), Active Power (P), Reactive Power (Q), 3 Phase Voltage across 25kV grid (Vabc\_25), and 3 Phase Current across 25kV grid (Iabc\_25). These waveforms can be observed from “Fig. 4” as follows, based on these readings, the power efficiency (P) levels were evaluated via (10), for the circuit with GWO and without GWO were tabulated in table 1 as follows, which represents circuit performance under different simulation instances.

Based on these results and “Fig. 5”, it can be observed that the proposed model can improve the power efficiency levels by 8.5% after application of GWO, which makes it useful for a wide variety of real-time simulation use cases. Due to these advantages, the proposed model is useful for improving power efficiency for different DFIG based wind farms.

### IV. CONCLUSION

In this paper, optimal value of inertia constant for DFIG wind farm has been obtained for different loading condition, GWO optimization has been utilized. Because of this, the proposed model is able to enhance the power efficiency levels after the application of GWO by 8.5%, which allows it to be useful for a wide variety of various real-time simulation use cases. This is because of the fact that: It is possible that the model that has been

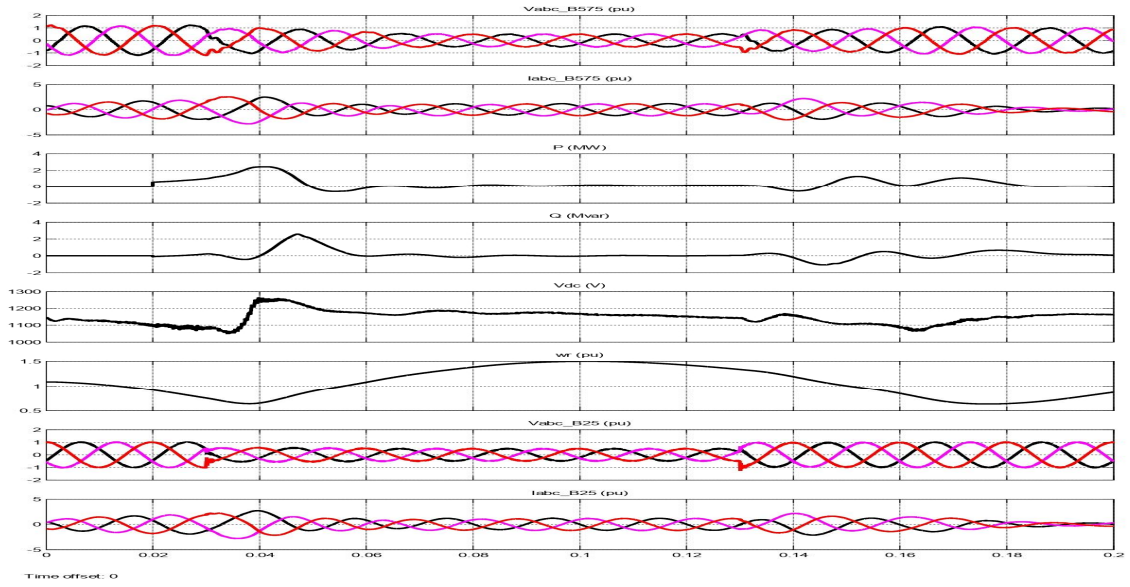


Figure 4. Output voltage & current levels for different component

TABLE I. RESULTS FOR DIFFERENT SIMULATION INSTANCES

| S. No. | Simulation Time (s) | Efficiency (%) Without GWO | Efficiency (%) With GWO | INERTIA CONSTANT WITH GWO |
|--------|---------------------|----------------------------|-------------------------|---------------------------|
| 1      | 1                   | 75.50                      | 86.50                   | 0.0931                    |
| 2      | 2                   | 76.80                      | 88.30                   | 0.9723                    |
| 3      | 3                   | 77.40                      | 89.40                   | 0.5302                    |
| 4      | 4                   | 78.30                      | 90.50                   | 0.7062                    |
| 5      | 5                   | 79.25                      | 90.80                   | 0.4057                    |
| 6      | 6                   | 80.15                      | 91.20                   | 0.1843                    |
| 7      | 7                   | 81.05                      | 91.20                   | 0.8000                    |
| 8      | 8                   | 81.95                      | 92.80                   | 0.9557                    |
| 9      | 9                   | 82.85                      | 93.57                   | 0.8968                    |
| 10     | 10                  | 83.75                      | 94.34                   | 0.5852                    |
| 11     | 12                  | 84.65                      | 95.11                   | 0.7640                    |
| 12     | 15                  | 85.55                      | 95.89                   | 0.4771                    |
| 13     | 18                  | 86.45                      | 96.66                   | 0.4658                    |
| 14     | 20                  | 87.35                      | 97.43                   | 0.0976                    |
| 15     | 25                  | 88.25                      | 98.20                   | 0.4858                    |

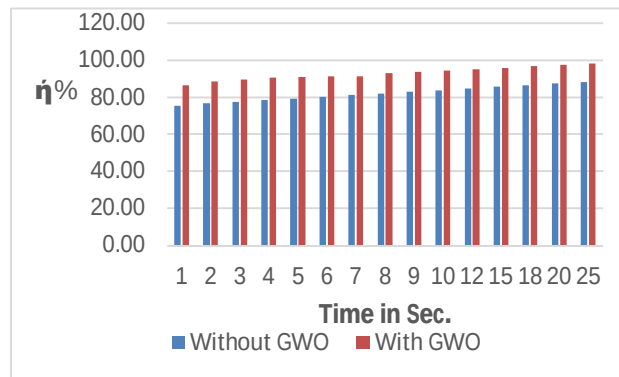


Figure 5. Power efficiency levels for different simulation instances

created may be successful in boosting the power efficiency of a variety of DFIG-based wind farms as a result of these advantages.

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