A Novel Crow Search based Strategy for Maximum Power Point Tracking of Wind Turbines Driven by Doubly Fed Induction Generator

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Abstract **- We propose a Maximum Power Point Tracking (MPPT) algorithm for grid linked to Doubly Fed Induction Generator (DFIG) for wind energy conversion systems. This Doubly-Fed Induction Generator (DFIG) is widely used in the upgrading market of Wind Energy Conversion System (WECS). It has the stator and rotor part, the stator part is linked directly on grid and its rotor part is linked on the back to back converter and (RL) filter respectively. RSC is responsible for the flow of power from stator part of DFIG to the grid. The Grid Side Converter (GSC) is responsible for assurance of controlling the DC voltage to specific value and to control the power flow initiates from rotor part of Doubly-Fed Induction Generator till the grid by altering the current filters. In this current paper, a latest intelligent higher power point tracker called crow search optimization for wind energy conversion system is used. The simulations are done in the software called MATALB/SIMULINK.**

Keywords - Wind turbines, Doubly-fed induction generator (DFIG), MPPT, Crow search

I. INTRODUCTION

Nowadays the renewable energy is so crucial on account of the environmental pollution and the restriction of fossil fuels in this world. The renewable sources produces very high amount of energy; however the fossil fuels are non-renewable. A very essential base of renewable energy is wind energy source [1]. The fast growing and the most dependent renewable energy source is wind for the economical variable. For changing speed operations, DFIG is the highly approved one and also has low converter rating in WECS.

The change occurs in the DC voltage on optimum value is assured by the usage of GSC, while the active and reactive power induced by Doubly-Fed Induction Generator till grid is controlled by the RSC [2]. In order to capture the higher power from the available wind MPPT algorithms can be employed. It can be done by performing the optimum steady voltage analysis across the load. Various MPPT techniques are involved in WECS in former literatures. Some of the literatures here include the following, they are algorithm of Hill Climbing Search, method of Incremental Conductance, method of Perturb Observe, Fuzzy Logic Controller and some other Evolutionary Algorithms [3].

Because of the simple and effective process of P&O method, it is a well known MPPT technique. P&O technique highly fails in analysing the MPPT due to high non linearity in wind speed and hence results in low power output due to the high fluctuations. The PI control method is so simple to carry out [4]. Due to the arbitrary selection of parameters, PI control lacks in efficiency [5]. For overcoming this problem FLC is employed to draw out the maximum power from the wind. The non linearity of the system can be analysed by FLC and it gave higher output for the present wind [6]-[7].

The aim of this paper is the effective use of MPPT techniques and the optimization of control parameters on the grid side converter, thereby making a high performance WECS. The main intention of the research is associated with voltage regulation at the grid side is to reduce the settling time, rise time, overshoot and undershoot problems, low transient response and high computational complexity These have been achieved by using P&O algorithm, PI controller, FLC and Crow search Optimization. The rest of the paper follows, modelling of wind energy conversion system of wind energy source on the basis of Doubly-Fed Induction Generator, and strategy of controlling WECS, simulated results and the discussions and finally the proposed systems is recommended.

II. DESIGN OF WECS ON THE BASIS OF DFIG

The DFIG is linked directly with the grid as shown here in figure 1. The stator part is linked to the Alternative Current (AC) mains here, while the wound rotor is supplied from the converter of power electronics through the slip rings to permit the DFIG to work at different speeds which follows the variation in the speed of wind. The usage of MPPT is frequently increased with higher energy conversion which starts from wind turbine up to the grid.

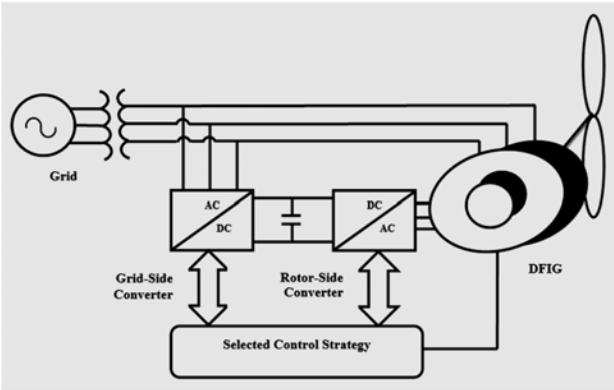

Fig 1. WECS diagram

A fine designing of reference of park frame of the DFIG is applied here. The voltage and flux equations of the DFIG are given below:

$$\begin{cases} V_{ds} = R_s I_{ds} + \dfrac{d\varphi_{ds}}{dt} - \omega_s \varphi_{qs} \\ V_{qs} = R_s I_{qs} + \dfrac{d\varphi_{qs}}{dt} + \omega_s \varphi_{ds} \\ V_{dr} = R_r I_{dr} + \dfrac{d\varphi_{dr}}{dt} - (\omega_s - \omega_r)\varphi_{qr} \\ V_{qr} = R_r I_{qr} + \dfrac{d\varphi_{qr}}{dt} - (\omega_s - \omega_r)\varphi_{dr} \\ \varphi_{ds} = L_s I_{ds} + L_m . I_{dr} \\ \varphi_{qs} = L_s I_{qs} + L_m . I_{qr} \\ \varphi_{dr} = L_r I_{dr} + L_m . I_{ds} \\ \varphi_{qr} = L_r I_{qr} + L_m . I_{qs} \end{cases} \quad (1)$$

In the expressions given above, Rs, Rr, Ls and Lr are the resistance and inductance values of the windings of stator and rotor respectively, and the following that mutual inductance produced here falls asLm.vdr, vqr, vds, vqs, ids, iqs, idr, iqr, φds, φqs, φdr, and φqr are d and q parts of stator voltages and rotor voltages, currents and flux, here ωr is the speed of rotor in the electrical degree.

A. Maximum Power Point Tracking

Maximum power point tracking is doing a vital role in the WECS since they tend to increases the power obtained from wind, and hence it enhances the efficiency of conversion.

In Fig.2, the Maximum power point tracking controller is showing the way of analyzing the peak power point. The simulation is done by different value which gives the best results are taken as the value of K. If the sampling instant is found to be raised the power must be present, i.e. $\Delta Pm\ (n) > 0$, the command speed ωr is reduced. If the sampling instant is found to be lowered, i.e. $\Delta Pm\ (n) < 0$, then, the command speed is reduced. Variations in the power output from the generator of wind suggest that, the turbine frequently works from its MPPT, without special interface measures. The related losses can be reduced by the usage of MPPT that assures that it has high energy passed to grid from the wind turbine.

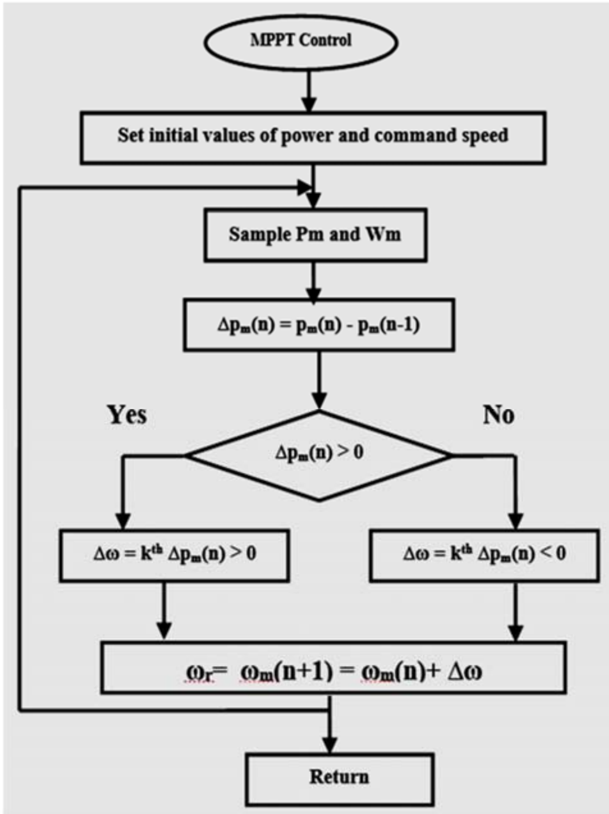

Fig 2. Flow chart for MPPT controller

B. Crow search optimization

The most intelligent birds are considered to be the crow family. They contain the brain larger than proportional to their body size. Crows are known for watching various birds, watching them, conceal their foods, and rob it once they leave. If a crow steals anything, it will do more effort like migrating, concealing its area for avoiding to become a victim of future, which uses their knowledge of being a theft to find the character of thief, and it can find the safe course to defend the storages of them from being theft.

The assumptions of Crow Search Algorithm are given below:

- Crows live in the nest.
- They memorize their hiding places positions.
- They follow one and other to do the robbery.
- They protect their storages from being theft by a probability.

The implementation of crow search algorithm is given in this section in a step by step manner below:

Step 1: Initialize the Problem and Parameters Adjustment

The problem of optimization, variance of decisions and their constraints are explained. Then, the controlled parameters of CROW SEARCH ALGORITHM (nest size (N), high number of iterations (itermax), flight length (fl) and awareness probability (AP)) are measured.

Step 2: Initialize the position and memory of the crows

In a d-dimensional search space, the N crows are positioned randomly as the members of the nest. Asuitable solution of the given problem is delivered by each and every crow, and d is called as the number of decision variables. The memory of every crow is started. In the first iteration experience of the crow is none; which states that they have concealed their food items from their starting position.

$$Crows = \begin{bmatrix} X_1{}^1 & X_2{}^1 & \cdots & X_d{}^1 \\ X_1{}^2 & X_2{}^2 & \cdots & X_d{}^2 \\ \vdots & \vdots & \vdots & \vdots \\ X_1{}^N & X_2{}^N & \cdots & X_d{}^N \end{bmatrix} \quad (2)$$

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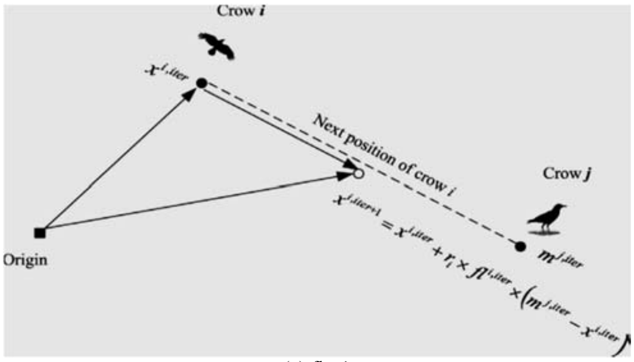
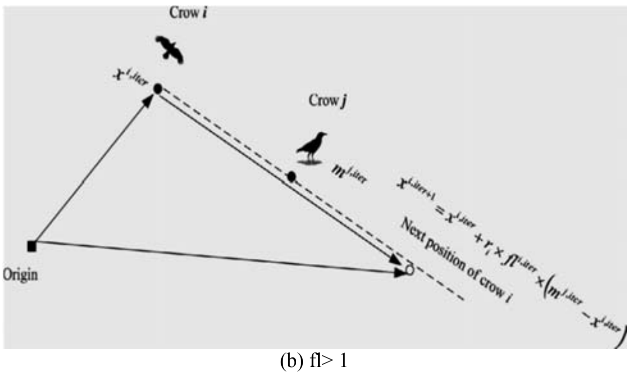


(a) fl< 1



(b) fl> 1

Fig 3.Crow Search Algorithm (a) fl<1 and (b) fl>1

$$Memory = \begin{bmatrix} m_1{}^1 & m_2{}^1 & \cdots & m_d{}^1 \\ m_1{}^2 & m_2{}^2 & \cdots & m_d{}^2 \\ \vdots & \vdots & \vdots & \vdots \\ m_1{}^N & m_2{}^N & \cdots & m_d{}^N \end{bmatrix} \quad (3)$$

Step 3: Calculation of fitness functions

For every crow, the qualities of their positions are calculated by inducing the decision variable values into their objective functions.

Step 4: Produce new position

Crows produce latest position in searching the space which is given below: if a crow (i) wants to produce a latest position. Because of this goal, the crow chooses one of the nest crows randomly (for example crow j) and following it to find the place of the food items concealed by the crow (mj). The new position of crow(i) is founded by Equation. (4). This procedure is done for the whole crows.

Step 5: Verify the possibility of new positions

The possibility of the new place of every crow is verified. Suppose the new place of a crow is possible, it will upgrade its place. If not, the crow will stay in same place and will not migrate to the upgraded new place.

Step 6: Calculate suitable function of new positions

The suitable value of function for the new place of every crow is calculated.

Step 7: Upgrade memory

The crows upgrade their memory as given below:

$$m^{i,iter+1} = \begin{cases} X^{i,iter+1} & f(X^{i,iter+1}) \textit{is better} \text{ than } f(m^{i,iter}) \\ m^{i,iter} & o.w. \end{cases} \quad (4)$$

Where f(.) implies the objective function value.

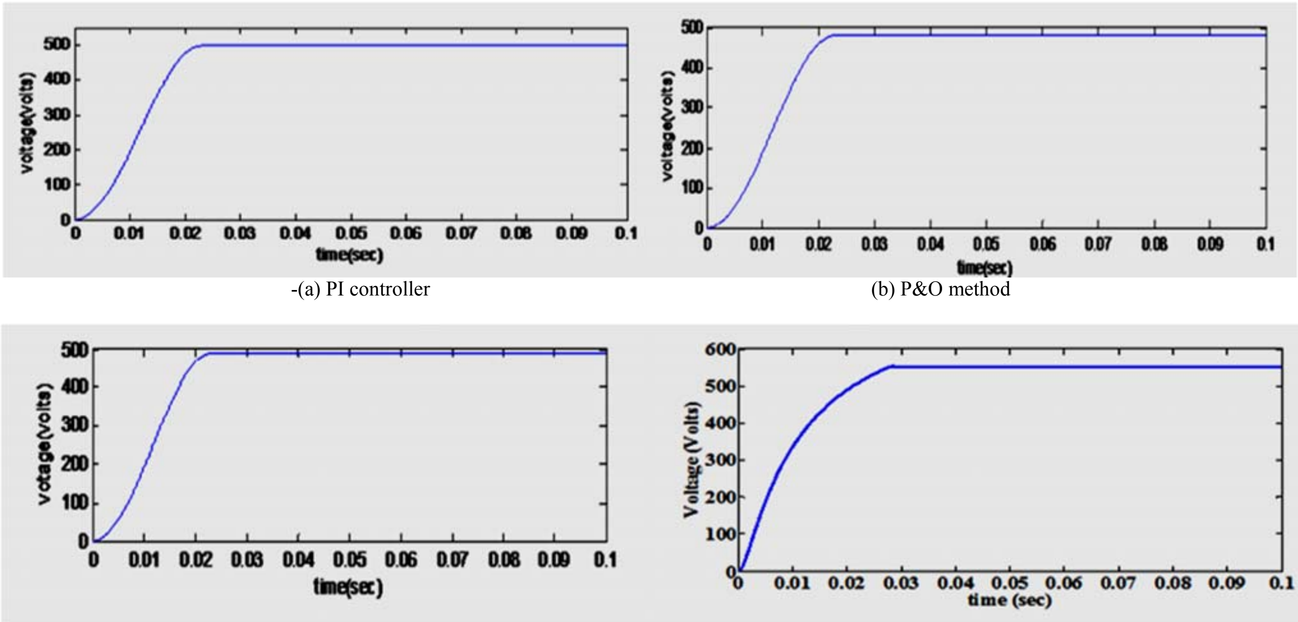
It shows that if any suitable functional value of the newly found place of a crow is good when comparing with the other suitable functions of the memorized area, the crow will upgrade its memory to the new place.

Step 8: Check the final criterion

Steps 4–7 are done till itermax is obtained. If the final position is obtained, the correct positions of the memory in the objective function values are resulted as the result of the problem of optimization.

III. SIMULATION RESULTS AND DISCUSSIONS

The simulated results of the voltage output comparison of MPPT controllers are shown in figure.4. The performance of every MPPT controller power output is compared here as shown in Figure.5. The simulation for crow search based MPPT method is carried out at the high output voltage and power when compared with the other controllers.



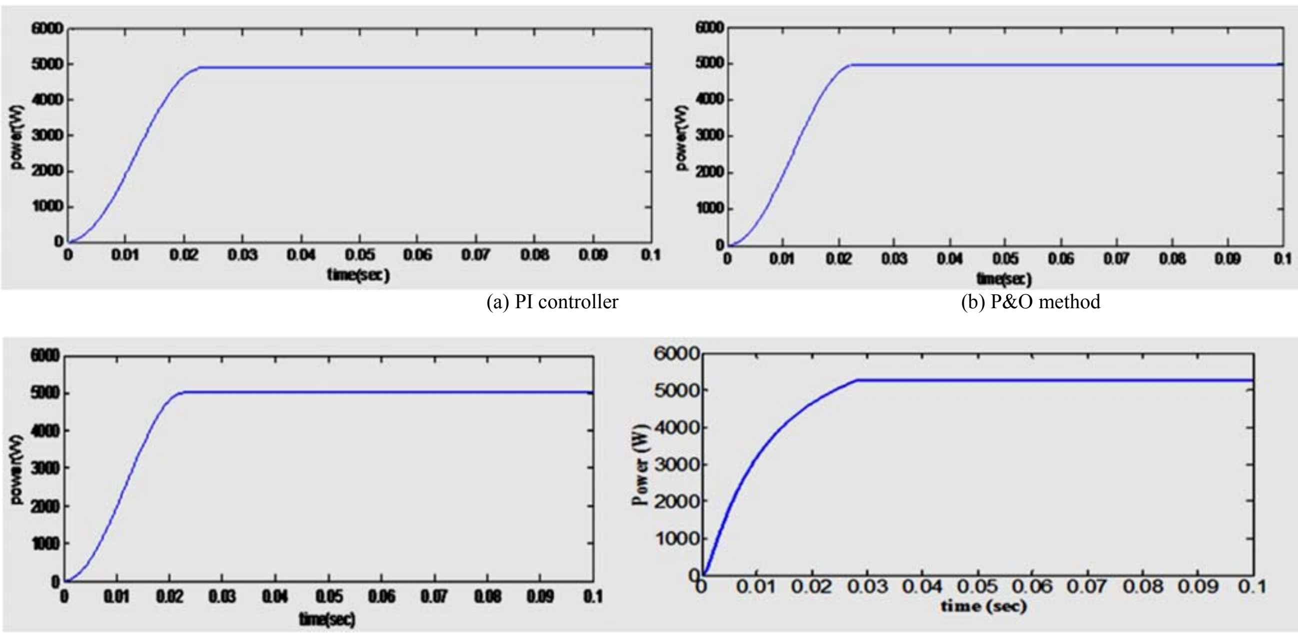
-(a) PI controller

(b) P&O method

(c) Fuzzy logic controller

(d) Crow search optimization

Fig. 4. Output voltage comparison of MPPT techniques



(a) PI controller

(b) P&O method

(c) Fuzzy Logic Controller

(d) Crow Search Optimization

Fig. 5. Power obtained by different MPPT techniques

The performance of PI, P&O, FLC and cuckoo search optimization based MPPT controllers is compared as shown in Table I.

TABLE I. OUTPUT OF VARIOUS MPPT TECHNIQUES

Parameters	PI	P&O	FLC	Crow Search
Power	4992 W	5093W	5112W	5220W
Voltage	491 V	494V	500V	570V

The crow search optimization has the high power out when compared with the PI, P&O and Fuzzy controllers. The output voltage of crow search optimization is equal to the reference DC voltage estimated to be the DC bus voltage of 570V.

TABLE II. COMPARATIVE ANALYSIS FOR TIME DOMAIN SPECIFICATIONS AND PERFORMANCE CRITERIA

TYPE	PI	P&O	FLC	Crow Search
Rise time, tr (sec)	0.33	0.22	0.21	0.01
Settling time, ts (sec)	0.98	0.7	0.6	0.074
Peak Overshoot (%)	-	-	-	-
Steady-state error, ess (%)	1.2	0.9	0.5	0

Time domain specifications like rise time, settling time, Peak overshoot and steady-state error is obtained for PI controller, intelligent controllers and the optimization performed here and thus obtained results are tabled in table II.

TABLE III. COMPARATIVE ANALYSIS OF PERFORMANCE INDICES

Type of Error	PI	P&O	FLC	Crow Search
ISE	0.09919	0.06774	0.0643	9.537e-7
IAE	862.8	547.1	546.8	42.37
ITAE	1726	1094	1088	12.22

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Performance indices like ISE, IAE and ITAE are also tabled below in table III. From the table ISE, IAE and ITAE are very much lowered in Crow Search than all other techniques of control.

IV. CONCLUSION

A MPPT analyzing algorithm was developed for extracting the highest power from the wind turbine using the optimization technique of crow search. 'Perturb and Observe' (P&O) method, 'Proportional Integral' (PI) control and 'Fuzzy Logic Controller' (FLC) were compared in the proposed crow search optimization technique. Crow search optimization is a fast and efficient technique to analyse the MPPT in WECS. The solutions obtained from Crow search optimization were: i) more efficient, ii) with high performance, iii) reduced execution time, iv) minimized the performance indices and v) provided excellent regulation of voltage and power.

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