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Sensorless Proposed Multi Sector Perturb and Observe Maximum Power Tracking For 1.5 MW Based On DFIG

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ABSTRACT:
This paper proposes a spirited method to defeat the problems of the conventional perturb and observe (P&O) maximum power point tracking (MPPT) and also used wind speed estimation MPPT. The suggested P&O can achieve the maximum power without large oscillation small settling time which means high efficiency for the system. The result of the suggested P&O compared with the traditional P&O, the two method uses wind speed estimation to estimate the wind speed to dispense using wind speed sensors. The adaptive P&O. This method uses additional curve which intersects with the power-speed curve and output 4 sector which used to facilitate the operating point so decide which step used in the operating section as the 4 sector P&O used small step and large step. If the operating sector is near the maximum power point (MPP) the large step used otherwise the small step used. This method is us the optimum power with small time and small oscillations compared to the traditional P&O. This word with 1.5 MW wind turbine based on doubly fed induction generator (DFIG) .the DFIG connected to the grid directly with the stator windings, and through back to back converter for rotor windings.
KEYWORDS: *DFIG ,WECS,BTBC ,MPPT ,P&O, CPO ,AD-PO*

I. INTRODUCTION

Exhaustion of customary vitality sources and petroleum products is considered a standout amongst the most basic issues that shed the light on inexhaustible vitality sources. Moreover, renewable energy sources (RESs) consolidates some imperative merits, for example, aggressive working expense with no environmental contamination issues. Among various RESs, wind power entice researchers because of clean, vitality, quick extension and rapid increasing compared with different wellsprings of electrical energy[1]. Wind energy has taken an undeniably essential place in the field of renewable energy generation. This type of energy is produced due to the worldwide developing of power request and the pattern towards inexhaustible and clean energy sources in the world[2-5].With quickly expanding limit of introduced wind energy conversion systems (WECSs), diverse WECSs have been recommended and approved in the researches. These frameworks can be sorted into two fundamental types; settled or fixed speed, and variable-speed WECSs. Despite the fact that the fixed speed WECSs are less difficult and less expensive than the variable-speed ones, variable speed WECSs are progressively effective since they have the adaptability to change the generator speed so as to follow the most optimal speed value[6]. (WECS) produce power from wind turbine as mechanical power which converted to electrical power by generator,WECS uses many types of generators as example there is most used two types is permanent magnet synchronous generator (PMSG) and doubly fed induction generator (DFIG),DFIG is the most used in WECS as it is preferred in industry for its great advantages [8] DFIG connected in WECS with grid as follow for rotor terminals its connected using back to back converter (BTBC) and for the stator winding it linked direct with the grid [9, 10].extracting maximum power process depend in addition of generator's type also on maximum power point tracking (MPPT) method which used to guarantee extracting the maximum power under several conditions of wind speed so the MPPT is the most important control tools [7, 11, 12].there is many types of MPPT used in WECS which consists two type of MPPT indirect power control (IPC) and direct power control (DPC). The IPC methods such as Tip Speed Ratio (TSR)[13, 14] power signal feedback (PSF) control [15]Wind speed estimation [16-19].and perturbation and observation (P&O) method is one of the DPC methods[20, 21]. straightforwardness of the P&O calculation is the legitimacy that makes it broadly utilized in MPPT for WECS[22].Moreover, the traditional P&O calculation does not require data about wind speed or wind turbine parameters[23]The P&O MPPT method, for WECSs, depends on perplexing the wind speed by a certain Step-size and predestine the adjustment in the output power until the inclination of the power-speed bend ends up zero. Subsequently, The customary type of the P&O strategy utilizes a settled step size. The choice of using fixed small step is a big risk cause of demerits as it backs off the controller reaction in addition of power losing. Also selecting large step has disadvantages, it produce power with large oscillations and what's more, diminishes the system performance. To defeat the drawbacks of traditional P&O techniques, variable step size and adaptive P&O procedures are utilized[24-32]. A Sensorless modified P&O solution depend on the slope of optimum power has been presented in[24].This technique takes care of the deviation issue of the traditional P&O calculation. in[25, 27] the authors succeeded in obtaining high efficiency. A proficient modified P&O MPP tracking has been researched in ,[26] notwithstanding, it requires the machine parameters, moreover the system non-linearity is dismissed. However, a large overshoot occurs at change of wind speed. In[32] two-organize adjusted variable step P&O venture is exhibited for MPPT in WECSs. This plan has utilized a middle variable, which is determined from the parameters of the system. Henceforth, this calculation has the disadvantage of system parameters reliance. WECS has difficulties with measuring wind speed directly under fluctuation of wind speed [33, 34] more over the WECS that used wind speed sensors it has disadvantage of high cost and need more maintenance that affect the performance and many times of failure [34-36].wind speed estimation defeat this problem of sensors and has good performance.

This paper proposes straightforward and effective solution for the traditional P&O by using an efficient P&O MPPT algorithm with adaptive variable step-size for gird tie DFIG-based WECS, as shown in Fig.1. The proposed method split the power-speed slope into four-divisions by insect the power-speed curve and another proposed curve. Every part has diverse recommended proportion, where the segments close to the MPP have small proposed proportion, though different divisions have large proposed proportion. Along these method, the proposed P&O guarantees high effectiveness and quick reaction. The proposed P&O presents a straightforward MPPT method, which effectively tracks the MPP at various wind speed. Fig .1 illustrate different types of MPPT algorithms.

This paper is organized as follows; section 2 presents an overview of the wind energy conversion system based DFIG and mathematical model for wind turbine and DFIG. Section 3 discuss the wind speed estimation , conventional P&O algorithm MPPT. The proposed four-sector P&O MPPT algorithm is presented in section 4. Section 5 shows the simulation results to valuation the proposed technique compared to the conventional P&O MPPT algorithm. Finally, the concludes the paper in section 6.

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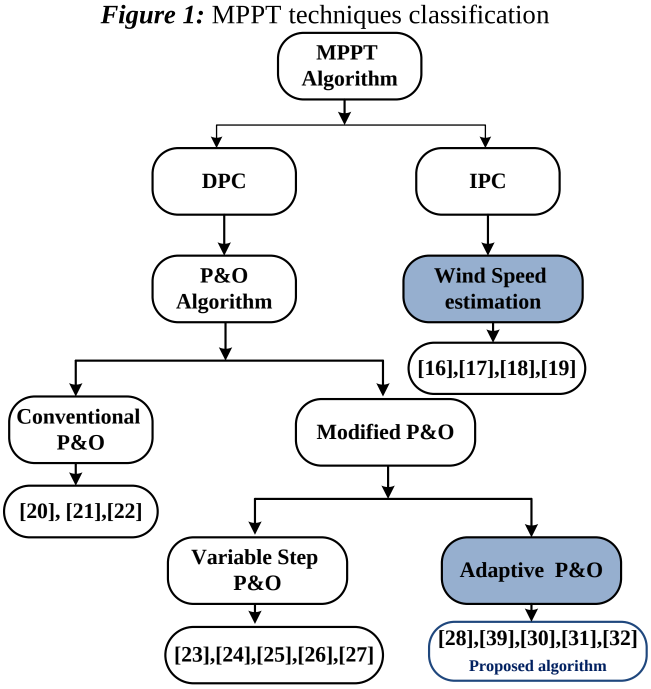
Figure 1: MPPT techniques classification



II. WIND ENERGY CONVERSION SYSTEM

As shown in fig.1 the WECS consist of wind turbine which connected with DFIG with mechanical system. And DFIG connected to the grid though stator terminals which is connected directly, and rotor connected (BTBC) to the grid ,the BTBC consist of rotor Side converter (RSC) which used to control the rotor speed to achieve the maximum power under variable under different speed, the second converter is called grid side converter (GSC) which connected directly and the main role of this converter to maintain the voltage of dc-link and control the reactive power, fig .2&3 illustrate the schematic of RSC and GSC as in [37].

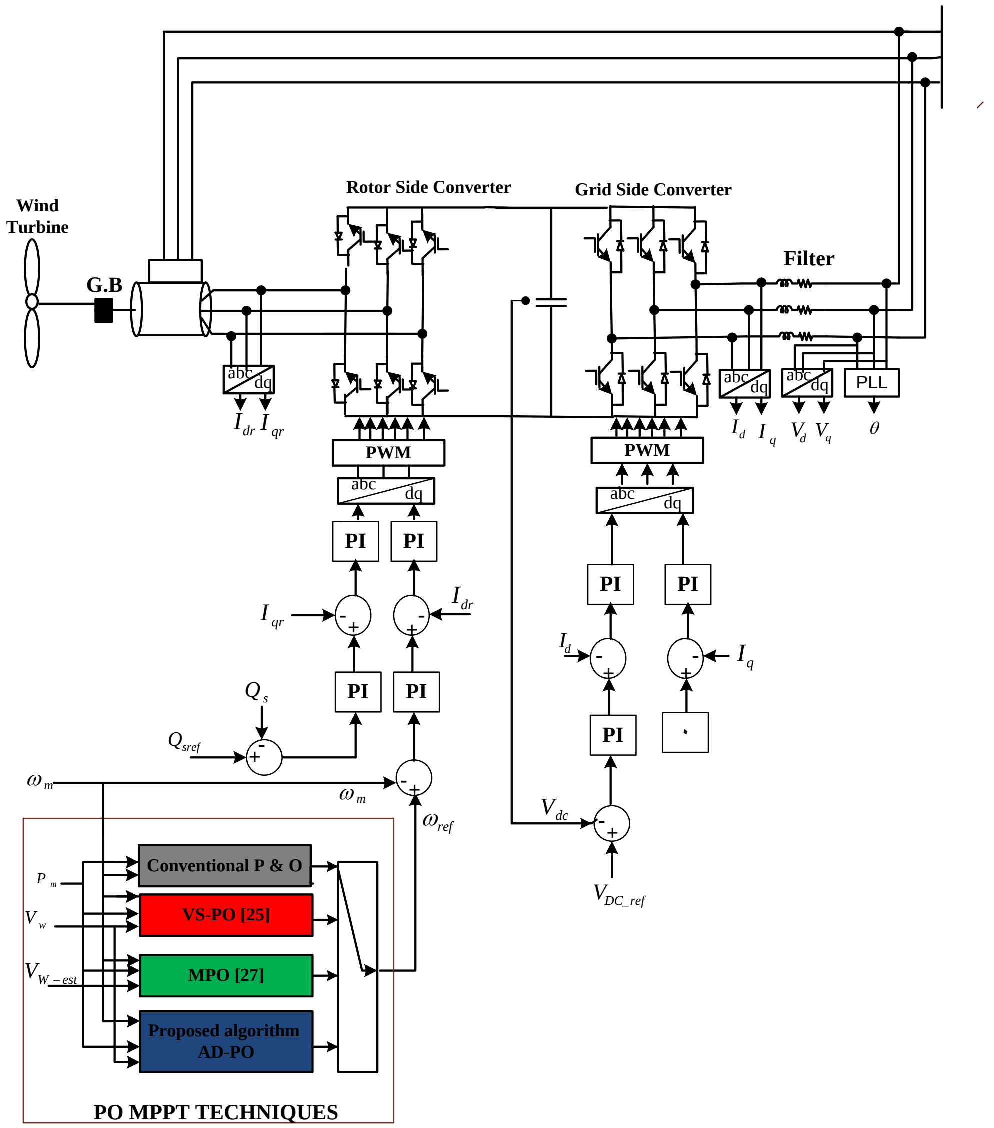


Figure.2 studied system

2.1 Wind Turbine model

The mechanical power can formulated as follow[38].

$$P_m = 1/2\, \rho \pi\, R^2 C_p(\lambda, ß) v^3{}_w \qquad (1)$$

and

$$\lambda = \omega_r R / v_w \qquad (2)$$

as the mechanical output power, is the air density, is the power coefficient of the wind turbine, is the wind speed , λ is the tip speed ratio, is the pitch angle, R is the radius of turbine blade and is the rotor speed.The power coefficient can formulated as follow [22]

$$C_p(\lambda, ß) = c_1 \left(\frac{c_2}{\lambda_i} - c_3 ß - c_4\right) e^{\frac{c_5}{\lambda_i}} + c_6 \lambda \qquad (3)$$

Where the parameters $C_1 - C_6$ are the approximated coefficient values $C_1 = 0.5167$, $C_2 = 116$, $C_3 = 0.4$, $C_4 = 5$, $C_5 = 21$, $C_6 = 0.0068$.
And

$$\lambda_i = \frac{1}{\lambda + 0.08ß} - \frac{0.035}{ß^3 + 1} \quad (4)$$

To extract the maximum power the power coefficient should be at its maximum value with different value of λ as illustrated in eq.3.at each wind speed there is optimal rotor speed which achieved when C_p is at its maximum value and λ at its optimal value and as a result maximum extracted. Condition changes rapidly so the rotor speed should be changes with wind speed variations as we can achieve maximum power. By regulating rotor speed and keeping operating points on the maximum value of C_p this clear in power–speed characteristic curve of a turbine illustrated in Fig4. The maximum value of MP curve changes with wind speed variation [39, 40].
In fig 4 each curve identified by optimal rotor speed correspond to each wind speed that achieve maximum power point (MPP) goal of extracting maximum power.
In fig.5 is the illustration of the relation between λ and C_p as λ should be at maximum value which make rotor speed must be at the optimum speed corresponding to MPP and as resultof λ optimum value C_p optimal value achieved. in this paper pitch angle β is zero.

2.2 DFIG Model
In [41, 42] the DFIG model equations can be formulated as follow:
Stator voltage equations:

$$v_{ds} = r_s i_{ds} + \frac{d\emptyset_{ds}}{dt} - \omega_s \emptyset_{qs} \quad (5)$$

$$v_{qs} = r_s i_{qs} + \frac{d\emptyset_{qs}}{dt} + \omega_s \emptyset_{ds} \quad (6)$$

Rotor voltage equation:

$$v_{dr} = r_r i_{dr} + \frac{d\emptyset_{dr}}{dt} - \omega_r \emptyset_{qr} \quad (7)$$

$$v_{qr} = r_r i_{qr} + \frac{d\emptyset_{qr}}{dt} + \omega_r \emptyset_{dr} \quad (8)$$

where v_{sd} & v_{qs} are stator voltage dq-axis, v_{dr} & v_{qr} are rotor voltage dq-axis ω_s is synchronous speed and $\emptyset_{ds}$ are stator flux dq-axis $\emptyset_{dr}$ & $\emptyset_{qr}$ are rotor flux dq axis, i_{dr}, i_{qr} are rotor currentdq axis, ω_r is rotor speed i_{ds}, i_{qs} are stator current dq axis,. r_s & r_r are stator & rotor resistances
Stator flux equation:

$$\emptyset_{ds} = L_s i_{ds} + M i_{dr} \quad (9)$$

$$\emptyset_{qs} = L_s i_{qs} + M i_{qr} \quad (10)$$

Rotor flux equation:

$$\emptyset_{dr} = L_r i_{dr} + M i_{ds} \quad (11)$$

$$\emptyset_{qr} = L_r i_{qr} + M i_{qs} \quad (12)$$

Where L_s, L_r are stator and rotor inductances and M is mutual inductance
Electromagnetic torque equation:

$$T_{em} = \frac{3}{2} p \left(\emptyset_{ds} i_{qr} - \emptyset_{qs} i_{dr}\right) \quad (13)$$

Where T_{em} is electromagnetic torque, p is number pairs of poles.
The active & reactive power at stator represented as follow:

$$P_s = \frac{3}{2}\left(v_{ds} i_{ds} + v_{qs} i_{qs}\right) \quad (14)$$

$$Q_s = \frac{3}{2}\left(v_{qs} i_{ds} - v_{ds} i_{qs}\right) \quad (15)$$

Where P_s&Q_s are stator active and reactive power.
The active & reactive power at rotor represented as follow
:

$$P_r = \frac{3}{2}(v_{dr} i_{dr} + v_{qr} i_{qr}) \quad (16)$$

$$Q_r = \frac{3}{2}(v_{qr} i_{dr} - v_{dr} i_{qr}) \quad (17)$$

Where P_r&Q_r are rotor active and reactive power

2.3 Shaft system model

The shaft system can be modelled as a single lumped-mass system with the lumped inertia constant H_m, calculated as in [43]:

$$H \quad (18)$$

as H_t is the inertia constant of the turbine and H_g the inertia constant of the generator.
the following equation is for the electromechanical dynamic:

$$\frac{d}{} \quad (19)$$

the rotational speed of the lumped-mass system is represented by ω_m which equal to ω_r that represent the rotor speed.ω_m and ω_r are given in per unit. the damping of the lumped system represented by D,and for the mechanical represented by the symbol T_m .as $T_m = \frac{P_m}{\omega_m}$.

Figure 3: mechanical power versus rotor speed at different wind speed

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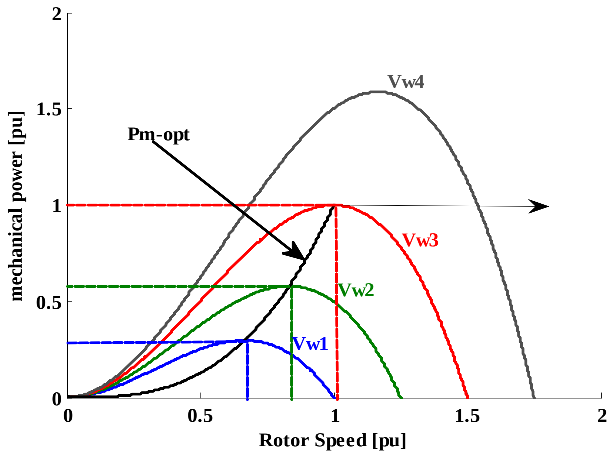


III. MPPT CONTROL

3.1Wind Speed Estimation MPPT Algorithm

This method can estimate the wind speed without using any speed sensors, first step it calculate the power coefficient $C_p$using third order polynomial as in [44]:

$$C_p = a_0 + a_1\lambda + a_2\lambda^2 + a_3\lambda^3 \quad (18)$$

Mechanical power can be calculated by using Eq.2 & 18 and then substitute in Eq.1:

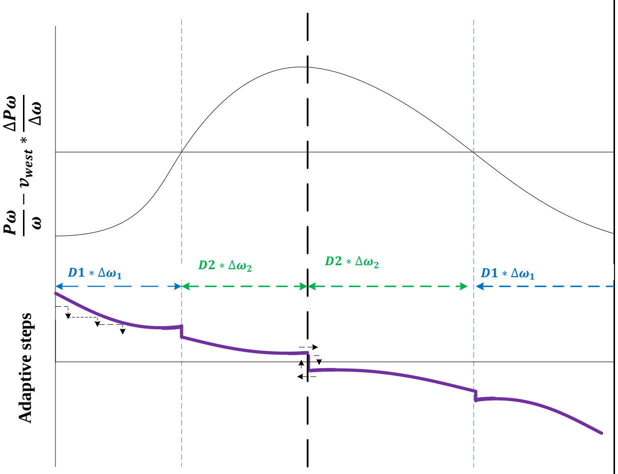
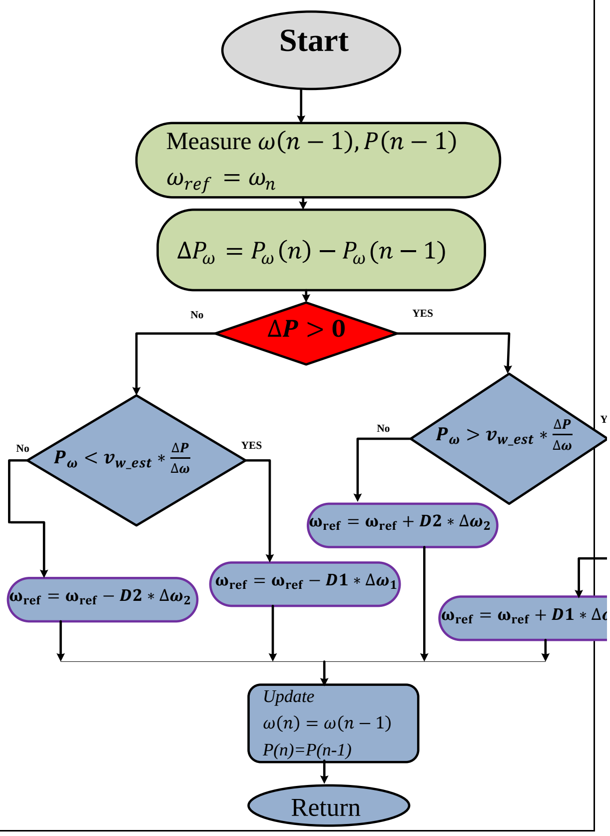
$$P_m = \frac{\rho A V_{wind}^3}{2}\left(a_0 + a_1\frac{\omega_m R}{V_{wind}} + a_2\left(\frac{\omega_m R}{V_{wind}}\right)^2 + +a_3\left(\frac{\omega_m R}{V_{wind}}\right)^3\right) \quad (19)$$

Wind speed can be calculated from Eq.19 as follow:

$$V_{wind}^3 + \frac{a_1}{a_0} R\omega_m V_{wind}^2 + \frac{a_2}{a_0}(R\omega_m)^2 V_{wind} + \frac{a_3}{a_0}(R\omega_m)^3 - \frac{P_m}{.5\,\rho A} = 0 \qquad (20)$$

As the values of the constants is as follow: a_0=0.00715814, a_1= -0.04454063, a_2=0.02899277, $a_3 = -0.00202519$

Finally the result of wind speed estimation calculated using the second root to solve Eq.20, which output three values ,the second value is the suitable[45].

Figure. 4. Adaptive P&O MPPT technique	Figure. 5.Flow chart of the adaptive P&O MPPT technique
	

3.4.The proposed adaptive p&omppt technique

The adaptive P&O algorithm change the perturbation size wisely which reduce the oscillation compared with other P&O methods. This MPPT depend on the four-sector MPPT technique[25]. However, the proposed algorithm improve efficiency and the performance of the WECS compared to the conventional P&O and the four-sector P&O MPPT technique. The proposed algorithm depend on the slope $\frac{\Delta P}{\Delta\omega}$ multiply of constant value, the constant value varies according to the operating sector. When the operating point is far from MPP it uses $L_1 * \Delta\omega_1$.Otherwise $L_2 * \Delta\omega_2$ is applied as shown in Fig.10 (b). Whereas the suggested ratio as follows [23]:

$$D_1 = M_1 * \frac{\Delta P}{\Delta\omega} \text{ and } D_2 = M_2 * \frac{\Delta P}{\Delta\omega} \qquad (21)$$

where, M_1 and M_2 are constant value. Whereas the selected value of M_1 is larger than the value $M_2$to reduce the oscillation in near sectors from MPP.

The main procedure of the proposed algorithm illustrated in the flowchart of the adaptive P&O algorithm as shown in Fig. 5

IV. SIMULATION RESULTS AND DISCUSSION.

To approve the adequacy of the proposed P&O MPPT system, two diverse wind speed profiles are considered. In the first case, the wind speed profile differs as various advance change with average value of 11 m/sec.in the second profile, the wind speed fluctuates arbitrarily with average speed 10m/sec and 20% choppiness The simulations results obtained from the adaptive P&O (AD-PO) techniques are compared with the traditional fixed step-size P&O using small and large step-size, and the four-sector P&O. The parameters of the system under study are given in Table I.

Table 1: *System parameters as in[46, 47]*

Specification of wind turbine

The coefficients C1 to C6	$C_1 = 0.5176$	$C_2 = 116$
	$C_3 = 0.4$	$C_4 = 5$
	$C_5 = 21$	$C_6 = 0.0068$

Blade radius	$R = 35.25\ m$
Air density	$\rho = 1.225 kg/m^3$
Optimal tip speed ratio	$\lambda_{opti} = 8.1$
Maximum powerCoefficient	$C_{p-max} = 0.48$
lumped inertia constant	H_m=4.4 s
damping lumped	D=0 p.u

DFIG parameters

Rated power	$P = 1.5\ MW$
Pole pairs number	$n_p = 3$
Stator resistance	$R_s = 0.023\ p.u$
Stator inductance	$L_s = 0.18\ p.u$
Moment of inertia	$H = 0.685\ s$
Mutul inductance	$M = 2.9\ p.u$

DC bus and gird parameters

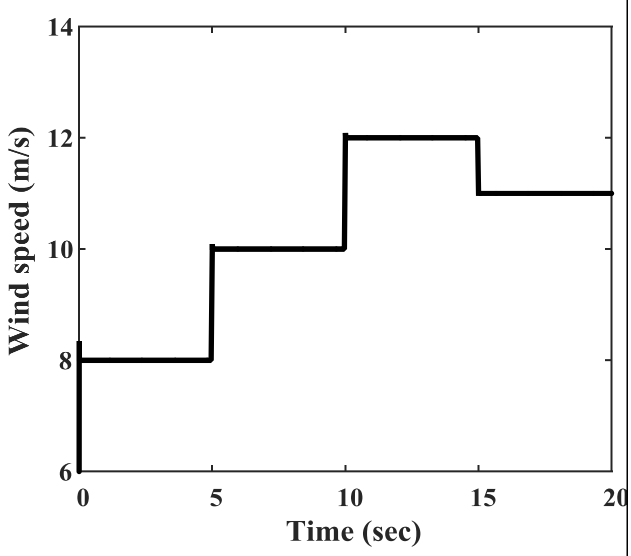
Dc-link voltage	V_{dc} = 1150V
Capacitor of the dc-link	C = 0.01 F
Grid voltage	V_g = 575 V
Grid frequency	F = 60 Hz
Grid resistance	R_g = .003 pu
Grid inductance	L_g = .3 pu

4.1 Step wind speed

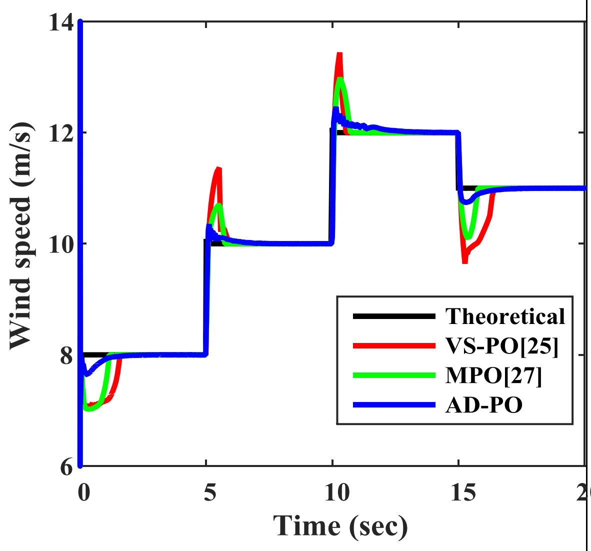
fig 6shows the simulation results of the MSC. The wind speed variety as step change work with mean value 10 m/sec is illustrated in Fig. 14a. Be that as it may, the wind turbine works at the ideal value of the power coefficient 0.48 as shown in Fig. 14b, which implies extricate the optimal power over simulation times as shown in Fig. 13c. it's clear that the system reaction with large step size PO (LS-PO) is faster than the small step size PO (SS-PO) and variable step size PO (VS-PO), and adaptive P&O (AD-PO) with settling time (100 ms) sec. but a large oscillation clear in LS-PO algorithm with (5 rad/sec) peak-to-peak ripples. contrariwise a small oscillations in AD-PO with (0.05 rad/sec) and small settling time (800 msec) with compared to VS-PO and SS-PO as shown in Fig.13b.furthermore, The settling time of AD-PO is smaller than both the VS-PO and the SS-PO wind speed change as shown in Fig. 14c.as the settling time of SS-PO and VS-PO is large it's affect negatively at the produce mechanical and reduce its value and furthermore lessens the general effectiveness of the system. the tip speedratio is its optimum value 8.1 for AD-PO overall simulation time as shown in Fig. 14d. The tip speed ratio value for LS-PO has large oscillation around the optimal value 8.1. moreover the rotor speed tracks the reference value under change of wind speed as shown in Fig. 13e.in addition under wind speed variation the AD-PO has small overshoot compared with VS-PO and SS-PO which have large overshoot as shown in Fig.14e. The simulation results under step change wind speed demonstrates that proposed AD-PO displays an effective tracking performance versus the fixed step and variable step PO. The results of the conventional and modified techniques are listed in Table II.

Table II
Comparison Between The Conventional And Proposed P&O MPPT Technique For WECS

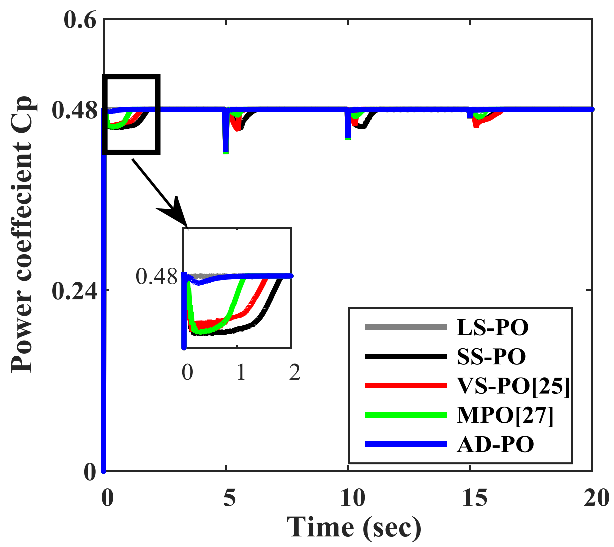
MPPT Algorithm	Speed ripple (P.P)rad/sec	$\Delta\omega$ rad/sec	Settling time (msec.)	$\Delta\omega$ rad/sec (10 to 12 m/sec)	η_{sys}
Conventional small-fixed step P&O	**0.05**	$\Delta\omega_1$ =0.02	**1900**	**15**	**84%**
Four-sector P&O [25]	**0.05**	$\Delta\omega_1$ =0.02 $\Delta\omega_2$ =0.1	**1600**	**15**	**86%**
PROPOSED AD-PO	**0.05**	M1=	**800**	**1**	**88.5%**



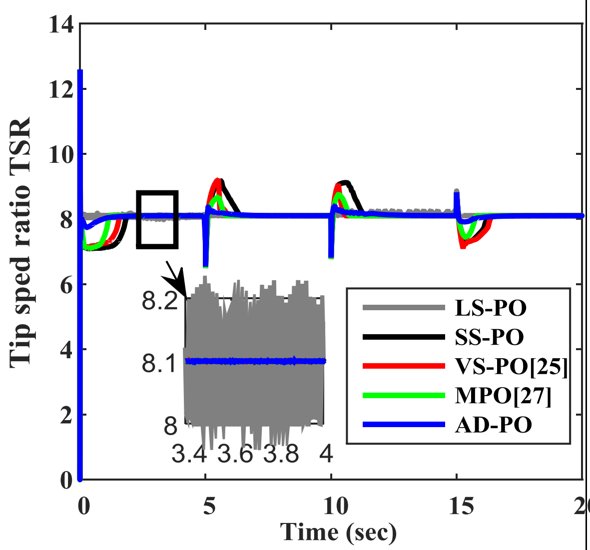
a) Wind speed



b) Wind speed estimation



c) Power coefficient



d) Tip speed ratio

V. CONCLUSIONS

The issues of quick reaction, oscillation reduction and the system effectiveness increments are inspected in this paper. a novel MPPT method takes out the impediments in the traditional PO MPPT system. The proposed technique depends on the allocation the power-speed curve into four-part. The determination of the proposed proportion is reliant on the section. Four segments are utilized to represent the fundamental thought of the proposed method. The controller effective to choose the proper proposed proportion in various areas. in the most distant locales of the greatest power point MPP, the controller has effectively chosen the large recommended proportion to achieve the MPP in little time .In addition, in the nearby areas of the MPP, the controller demonstrated progressively viable in choosing the little proposed proportion to achieve the most extreme power with no oscillation The proposed P&O is explored on a large scale WECS .utilizing MATLAB/SIMULINK programming. To approve the quick and increasingly proficient activity of the proposed system, it is compared with the ordinary PO MPPT and VS-PO strategy. High effectiveness and straightforward task are the primary benefits of the proposed P&O. Also, the proposed P&O demonstrates a quick reaction with very small oscillation, which expands the general systems efficiency. The simulation results demonstrate that the system effectiveness is expanded from 84 % to 89%.

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