Integration of DFIG With Boost Converter Fed Grid Connected System Using P&O MPPT Control

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Abstract-Renewable energy sources (RES) are critical to meeting the world's predictable energy needs. The present electrical system design, which is built on electrical components has various unpredictable loads and distributed generators (RESs), which has resulted in the emergence of several PQ difficulties. This concept offers a combination of DFIG with a boost converter fed grid connected network controlled by P&O MPPT. It is proposed to build and a three-phase grid connected network with a novel configuration based on the use of winds. It incorporates a high-gain single-switch dc to dc Boost converter with P&O MPPT. The maximum power point detection method assists wind power plants in overcoming fluctuation in voltage concerns. A PWM rectifier is also employed to convert the DFIG's AC voltage to DC, and is then supplied into the MPPT method's boost converter-based output. To synchronize the grid, PI controllers and D-Q theory are utilized. The dc-link stable voltage is preserved in this study by using a PI controller. Furthermore, this reduces THD and conforms to the IEEE harmonic guideline. At last, we will run a series of numerical simulations with the MATLAB 2021a / Simulink program to evaluate the suggested controls. The MPPT tracking efficiency between the controllers shown the value as 88% for P&O.

Key Words: DFIG - Doubly fed induction generator, WT – Wind Turbine, PWM – Pulse Width Modulation, MPPT – Maximum Power Point Tracking, P& O – Perturbation and Observation.

1. INTRODUCTION

The better the performance, the lower the losses, and hence the lifespan of a generator is substantially longer than in older systems. A combination of technological accessibility and control practicality, the DFIG derived wind energy generating device is a popular choice in the current worldwide setting. However, the DFIG's efficiency remains a source of concern [1]. The primary purpose of creating this simulator is to replicate the various conceivable circumstances of a genuine wind farm based on a double feed induction generator. It will enable us to evaluate various energy transfer control approaches among the generator and the grid. The essential element of our strategy is to keep the hardware for this experimental bench as simple as possible, such as sharing the DC bus across both the DC motor and the DFIG and utilizing only one DSP control board to drive both motors [2]. The purpose of this research is to investigate the performance of a connected to the grid PV/wind combination under various operating conditions, such as fluctuations in solar irradiance and wind speed. A boost converter with PV for MPPT and a DFIG driven by a variable speed WT are used in the proposed system. In general, the DFIG is used in wind generating due to its various advantages, such as ease of installation, actual and reactive power regulation, and the capacity to lower maximum output from the WTs [3, 4]. Experts have used numerous MPPT control algorithms, including as perturb and observe, incremental conductance, and hill climbing, to generate the best power from PV panels and wind turbines [5]. The significance of possible renewable energy sources in comparison to traditional fossil fuels is discussed. The wind renewable energy technologies rely on the unpredictability wind velocity. Furthermore, the MPPT algorithm overcomes the non-linearity, fluctuation, and uncertainty of the wind system [6]. The P& O algorithm involves changing the voltage and measuring the power yield. Voltage increasing causes the power to grow if the action is on the left side of the MPP and to decrease if the activity is on the right side of the MPP [7].

A variable speed regular frequency wind power generating system must include MPPT. This work investigates the idea, features and stated methods for enhancement of primary systems in relation to current research on the MPPT algorithm [8]. In compared to the stator side which supplies a fixed frequency and voltage to the grid, the rotating side of DFIG offers variable frequency that is controlled by power converters prior to linking to the grid. These converters are used to manage a fraction of the total power so as to achieve independent full oversight of the engine's real and regenerative energy. Because the circuit around the rotor only receives a percentage of the total power [9]. A turbine farm with two DFIG-based wind turbines linked in parallel to a point of common connection that powers an induction motor via a feeder is used in the simulation. In addition, the isolated system's synchronizing to the main grid has been simulated confirming the proposed control system's capacity to effectively complete the process of repair. DFIG systems with Boost Converters solve power factor difficulties, resulting in more grid-friendly, as well as P&O MPPT control and compatibility for fluctuating climatic conditions in wind speeds. [10]. The involvement of the paper is using P & O MPPT to harvest the greatest power from a wind power system as well as to generate a high gain output DC voltage using the proposed MPPT with Boost converter. Grid synchronization can also be accomplished utilizing DQ theory and a PI controller and the Wind systems features are demonstrated using the MATLAB Simulink frame work.

2. Proposed System Explanation

Wind energy is generated via a DFIG that relies on a variable-speed wind turbine. The rotor-side and grid-side converters of DFIG's two controllers may generate and observe reactive power, maintain constant rotor velocity, and manage the voltage at the DC link. Because of its matured technology for control and great stability, DFIG-based windmills are currently the dominating wind turbines. Furthermore, MPPT of DFIG-based windmills is critical for improving wind power conversion efficiency.

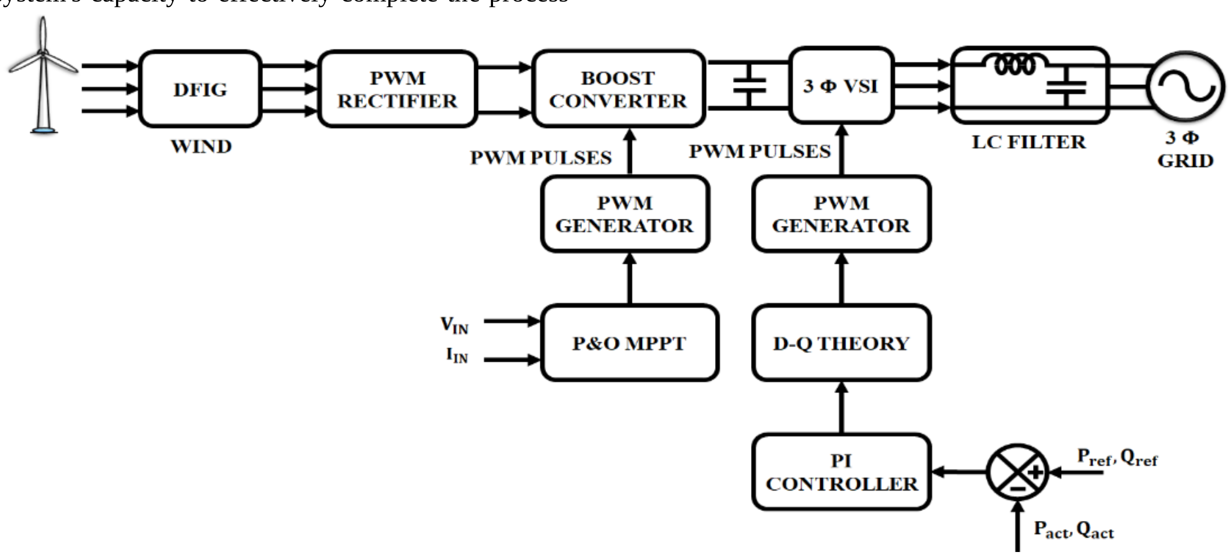


Fig.1. Proposed Diagram

From the wind turbines the DFIG generates power and supply to the PWM rectifier it connects to the boost converter. The voltage from DFIG which is AC, is converted into DC using PWM rectifier and fed to output of the boost converter based MPPT system. The grid synchronization is achieved by using PI controller and D-Q theory also connected to the PWM generator it operates the PWM Pulses and connected to the 3φ VSI. The output voltage and current is monitored by the P&O MPPT is also generated the PWM pulses connected to the boost converter. PI controller is used in this work for upholding the dc-link voltage constancy. The output from the 3φ VSI is transfers to the LC filter and supply to the 3φ grid.

3. Proposed System Modelling

3.1 DFIG

A DFIG is used to simulate the WT by altering the speed to generate different wind velocity characteristics. The twisted rotor intermittent generator DFIG has a grid and is related directly to both the stator and the rotor via a converter. For the sake of simplicity, the DFIG model is used, which is stated in an infinite rotating frame dq. The voltage equations of stator as well as rotor are expressed as,

$$\begin{cases} v_{ds} = R_s i_{ds} + \frac{d}{dt}\phi_{ds} - \omega_s \phi_{qs} \\ v_{qs} = R_s i_{qs} + \frac{d}{dt}\phi_{qs} + \omega_s \phi_{ds} \\ v_{dr} = R_r i_{dr} + \frac{d}{dt}\phi_{dr} - \omega_r \phi_{qr} \\ v_{qr} = R_r i_{qr} + \frac{d}{dt}\phi_{qr} + \omega_r \phi_{dr} \end{cases} \quad (1)$$

Where the stator as well as rotor are specified as s and r, the components of the synchronous reference frame are specified as d and q, the voltage is specified as v the current is specified as i, the flux is specified as ϕ, the frequency is specified as ω and the resistance is specified as r.

The flux equations of stator as well as rotor are expressed as,

$$\begin{cases} \phi_{ds} = L_s i_{ds} + M i_{dr} \\ \phi_{qs} = L_s i_{qs} + M i_{qr} \\ \phi_{dr} = L_r i_{dr} + M i_{ds} \\ \phi_{qr} = L_r i_{qr} + M i_{qs} \end{cases} \quad (2)$$

Where the mutual inductance is specified as M and the inductance is specified as L

The DFIG-based WECS mechanical equation is expressed as,

$$j\frac{d\Omega}{dt} = T_a - T_{em} - f\Omega \quad (3)$$

Where the DFIG speed is specified as Ω, The DFIG electromagnetic torque, which is expressed as,

$$T_{em} = p\frac{M}{L_s}\left(\phi_{qs} i_{dr} - \phi_{ds} i_{qr}\right) \quad (4)$$

Where the DFIG's pair of poles is specified as p.

The real as well as reactive power on stator side are expressed as,

$$\begin{cases} P_s = \frac{3}{2}\left(v_{ds} i_{ds} + v_{qs} i_{qs}\right) \\ Q_s = \frac{3}{2}\left(v_{qs} i_{ds} - v_{ds} i_{qs}\right) \end{cases} \quad (5)$$

3.2 Boost Converter

The Boost converter is widely recognized for its simple design and ability to handle low-distortion input currents. Passive components such as diodes, a power switch, and a controller are required for a DC/DC converter. The Boost converter works by opening and shutting an electronic switch, which is a switching converter, frequently. This converter raises the input voltage. Figure.2 shows a boost converter configuration with an IGBT as a power switch.

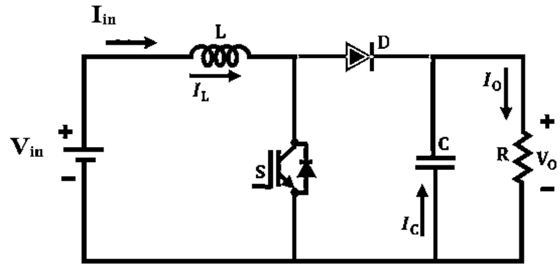
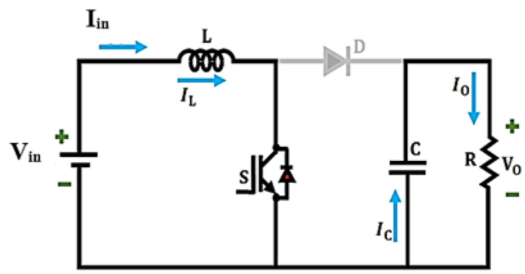
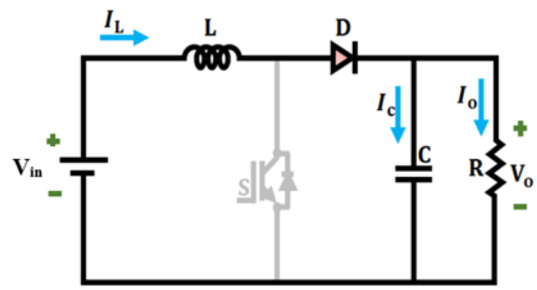


Fig.2.Boost converter (a) Circuit Topology



(b) Stage 1 Operation



(c) Stage 2 Operation

Stage 1: While mode 1 is engaged, inductor L stores energy and input voltageV_{in}, is supplied across it, as illustrated in Figure.2 (a). Diode D is in the OFF state due to its opposite bias and lack of conductivity. In contrast, in a discontinuity mode of functioning, the peak value of inductor current is determined from zero, but in an ongoing mode, it is generated from the main lowest value.

Stage 2: In mode 2, power switch S is turned off, inductance voltage is reversed, and value at the diode's junction increases above the voltage of the inputV_{in}, as shown in Figure 4.3 (b). Inductor L begins to release the energy it has been keeping by employing smoothing capacitor C, load R, and diode

$$V_{in} = L\frac{(I_2-I_1)}{T} = L\frac{\Delta I}{T_{on}} \quad (6)$$

Taking into account that inductor current falls linearly from I_2 to I_1 over time T_{off},

$$V_{IN} - V_o = -L.\frac{\Delta I}{T_{off}} \quad (7)$$

$$T_{off} = \frac{\Delta I.L}{V_O - V_p} \quad (8)$$

When V_{in} value is substituted in equation (7) get

$$T_{on} = \frac{V_o-V_{in}}{V_O.T_{off}.f}.T_{off} = \frac{V_o-V_{in}}{V_{o-f}} \quad (9)$$

$$\Delta V_C = \frac{I_O(V_o-V_{in})}{V_O.f.C} \quad (10)$$

The boost converter may therefore raise its electrical supply without using a conversion device, although the voltage gain is not very significant. This necessitates the replacement of the Boost converter with another high efficiency converter in order to provide more voltage gain.

3.3 Three Phase Voltage Source Inverter

A rectifier fed inverter system employs two stage converters. This paper discusses inverter side control. The rectifier side control is used to calculate duty cycle. The vast majority of inverter applications require voltage control. This control may be required due to variations in the transformer supply voltage and internal regulation. The typical power-circuit topologies of a three-phase voltage source inverter are depicted in Figure 3. It is divided into three separate categories: voltage regulation given to the inverter, voltage regulation within the inverter, and voltage output modulation.

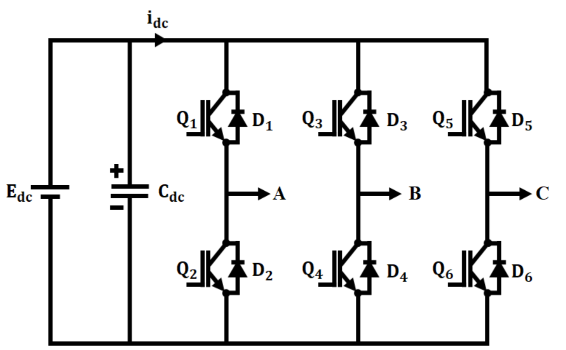


Fig.3. Topology of a 3-phase VSI

For purposes requiring medium output power, n-channel IGBTs are the preferable devices in these topologies, which only require a single dc source. In order to reduce stray resonance between the capacitance and the inverter switches, capacitors and switches are connected to the dc bus using short leads, Switches Q1, Q2, Q3, and so on are quick and controlled. Fast recovery diodes D1, D2, D3, and so on are linked in anti-parallel with the switches.

4. RESULT AND DISCUSSIONS

The following outcomes are attained as a result of implementing the planned work in MATLAB simulation. The parameters specification of the proposed DFIG and boost converter is shown in Table.1

DFIG Specification			
Stator parameters		Rotor Parameters	
Supply Voltage	415V	Rotor Voltage	110V
Stator frequency	50 Hz	Resistance	8ohms
Inductance	2.8 kw	Rotor Speed	1459 rpm
Resistance	0.06H	Inductance	0.06H
L_1	1.4mH		
C_1	$4.8\mu F$		

Figure 4 shows the DFIG output waveform, it has the continuous value as 200V and Figure.5, exposed the WECS rectifier output voltage waveform it increases from 0V and gets sudden drops from 400V after it has the value as 230V.

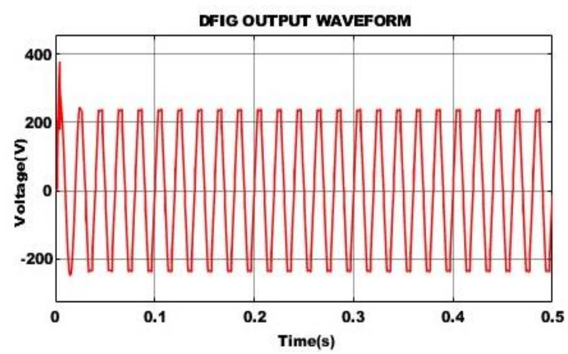


Fig.4. Converter Input voltage waveform

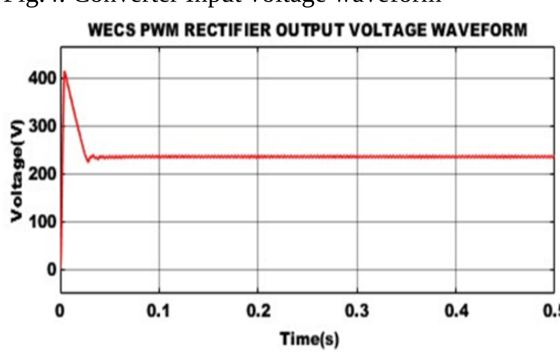


Fig.5. Converter Input Current waveform

Figure.6 and 7 depicts the PWM rectifier voltage and current waveform, the voltage has the continuous value as 230V and the current waveform gets varies, after 0.1 seconds it has the value as 0A also it slightly differs depending upon the time

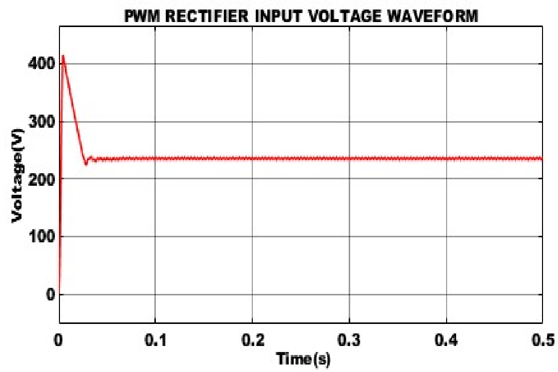


Fig.6. Converter Output voltage waveform

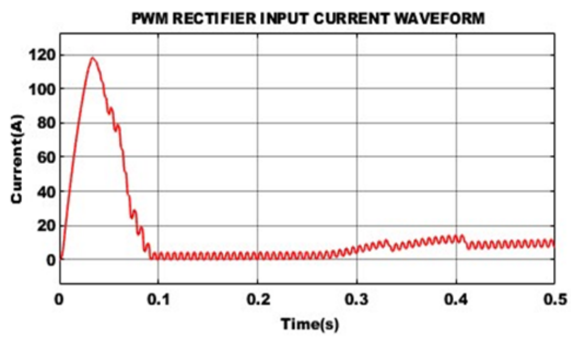


Fig.7. Converter Output current waveform

Figure.8 and 9 shows the output voltage and current of converters waveform, the voltage gets increases and drops from the 1000V after 0.3 seconds it maintains the value as 400V. The output current get increases and sudden drops from 10A, and it get varies values depending upon the time.

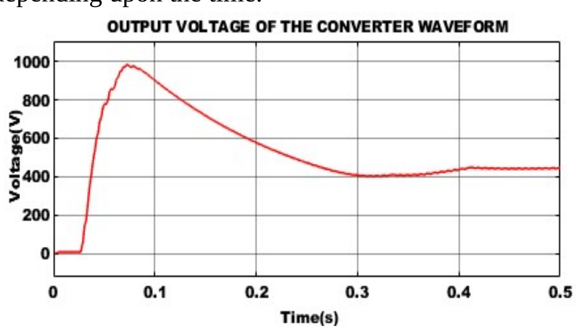


Fig.8. Power factor Waveform

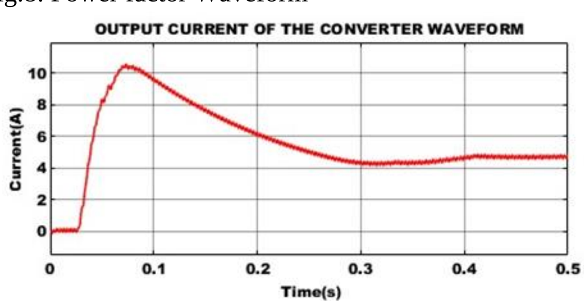


Fig.9. DFIG output voltage waveform

Fig.10 and 11 shows the grid voltage and current waveform, it has the constant value as 400V and 10A

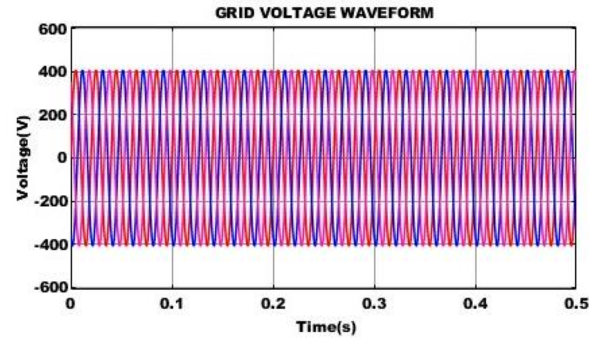


Fig.10. PWM rectifier voltage waveform

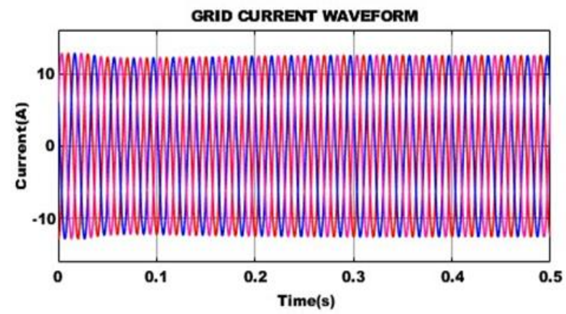


Fig.11. Battery SOC waveform

Figure.12, shows the Grid voltage and current waveform also Figure, 13, has the real power waveform. The grid voltage has the value of 400V and 0A, the real power waveform has the value of 8000 watt.

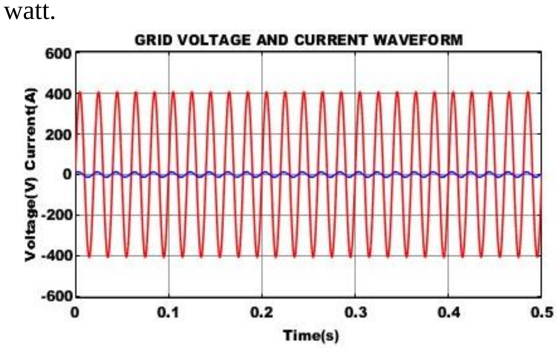


Fig.13 battery voltage waveform

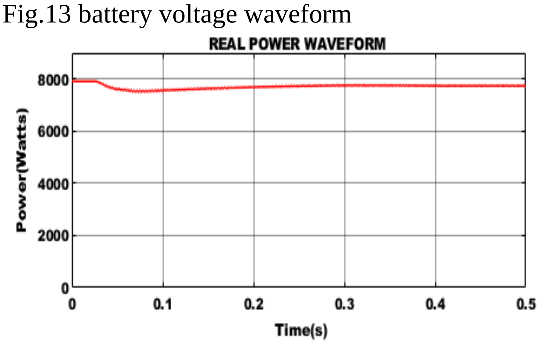


Fig.12. battery current waveform

Figure14, represent the reactive power waveform it has the value the magnitude of reactive power is moderately fewer, about $-150VAR$

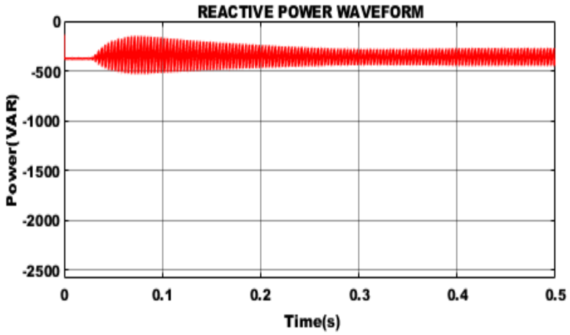


Fig.14. Reactive power waveform

Figure.15, shows the MPPT tracking efficiency between the controllers as INC (86%) and P&O (88%) respectively.

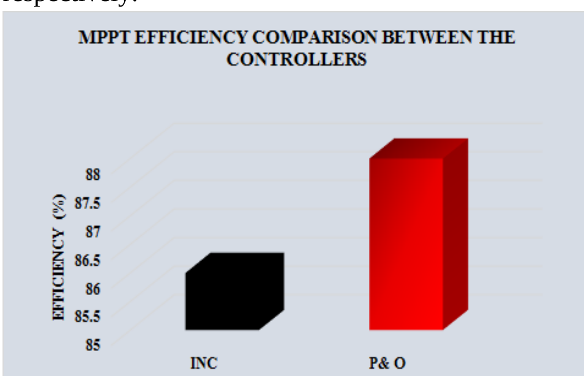


Fig.15. MPPT Efficiency comparison between the controllers

5. CONCLUSION

This proposal presents a revolutionary three-phase grid-connected system architecture based on wind energy conversion. The greatest power from the wind energy system is retrieved utilizing a Boost conversion with Perturb and the MPPT algorithm. For converting fixed DC voltage to variable frequency AC voltage, a 3 VSI is used. In this suggested technique, the reference current is extracted from the source current using PI-based D-Q theory for overtones and reactive energy minimization. With the help of a rectifier, the alternating current output from a wind turbine is converted to direct current in WECS. The rectifier output is routed into the MPPT system, resulting in optimum wind power use. The link power is delivered into the grid via a three-phase inverter, which aids in DC-AC conversion, and grid timing is accomplished via DQ theory. Grid synchrony is accomplished by matching the inverter output current to the injected grid voltage. Using the retrieved grid angle, the feedback values are translated into a suitable reference context. To test the efficiency of the WECS system, a simulation of it is constructed in MATLAB. In this paper the MPPT efficiency comparison between the controllers has the value of 88%.

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