Modelling of Variable Speed Wind Turbine Connected DFIG:250KW

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Abstract: - This manuscript initiates the design and analysis of a doubly-fed-induction-generator (DFIG) linked to the grid, aiming to assess a wind vitality conversion configuration employing an emulated wind turbine drive system. The generator's configuration involves integrating the d-q axes reference framework with the stator flux. Independent management of real, and imaginary power, along with the dc-bus potential at the grid, is achieved through the field-aligned regulating method. Controlling real, and Quadrature power, as well as DC-bus potential, is executed using tandem converters at distinct velocities, encompassing sub, syn, and hyper-synchronous speeds. The effectiveness of these control strategies is validated through the emulation of a variable-speed wind turbine-connected DFIG, showcasing precise control over DC voltage, reactive power, and active power.

Key-Words: - Wind turbine; double-fed-induction-generator; DC-bus potential; real and imaginary powers, tandem converters; Proportional-Integral (PI); Pulse Width Modulation (PWM).

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1 Introduction

The growth of any country relies on electric power generation and consumption, with a focus on utilizing sustainable energy sources. The transition to alternative energy sources, is propelled by anxieties regarding climate disruption, and, the imperative to decrease Subservience on non-renewable energy. Wind vitality is gaining prominence as an especially eco-friendly power source, given its abundant presence in various regions and the positive economic outcomes, linked to substantial vitality production. Consequently, the reliance on substantial aerogenerators, for energy production is steadily booming, as emphasized, [1]. The asynchronous generator, with dual feeding, is notably chosen as the prevailing alternator in wind turbines, owing to its intrinsic varying speed features, efficient regulating capabilities, improved efficiency, and reduced converter requirements for grid connection. The inherent capability of the asynchronous generator, with dual feeding resides, in managing the dynamics, and responsive power output demands from the load. Although power dynamics are contingent on wind availability, they are regulated, even if temporarily, by implementing instinctive active vitality. This highlights the significant role of DFIG, as a sustainable power resource within an integrated framework connected to the grid. In scenarios wherein minimum of two viable sources of power to enhance the consignment of power by regulating the DFIG's dynamics, the regulation of power is managed to fulfil the grid's needs. When confronted with an unreliable network marked by voltage fluctuations, the DFIG can be operated to generate the required level of imaginary power for the grid, thereby governing the voltage profile, as discussed, [2]. The advanced control capabilities, and the dynamic attributes of dfig's based on Variable Speed Constant Frequency (VSCF) technology, are crucial areas of focus in the research on wind-energy.

In a dual-fed configuration, two adjacent converters fulfil the requirement of providing energised current to the rotor circuit. Grid-connected converters (GSC), are linked to the grid, and function with a three-tier power system or three tier converters, while sustaining a consistent DC potential. The stabilized DC voltage serves as the source of power for the three-tier converter straightly linked to the rotor circuit, commonly known as a rotor-side converter (RSC).

The primary role of the GSC, is to elevate a stable DC potential. However, the GSC also possesses the capability, to regulate imaginary power, and offset imaginary power during unbalanced conditions, [3]. Conversely, the converter RSC supplies the necessary polarization current, to that rotor winding, facilitating the generation of crucial dynamic and imaginary power capabilities at the stator side.

The production of electric power might undergo, an increase of 2%–6% when utilizing varying hurtle wind turbines collated to wind turbines with a persistent rotational speed, [4]. On the contrary, [5], there is a potential for increasing power by up to 39%. The German brochure and others, [6], depict that the power produced with varying hurtle wind turbines can fluctuate in the range of 3% to 28%distinguished with persistent hurtle wind turbines, hinging on site conditions, and specific parameters.. Various studies, including others, [5], [6], [7], [8], [9], have presented the calculations of the electric power produced by the dfig. A more thorough examination of comparing the electrical circuits in wind turbines is needed. In their research, [10], investigated power generation across various methods, including a constant hurtle wind turbine with an asynchronous generator, a wind turbine with fully varying hurtle capabilities employing an inverter-supported asynchronous generator, and a variable-speed wind turbine utilizing a dfig. The use of a dual supported asynchronous motor, in performing as generation mode, enhances the production of electric power. In the context of a variable-hurtle system, utilizing a wound rotor asynchronous motor emanates in a 20% increase in the power of a dfig, and it experiences a 60% increase compared to a system with a constant speed.

It's crucial to emphasize that the investigation did not consider into account losses associated with wind distribution, electrical components, and machinery. Introduced and implemented the double-supported production strategy for reluctance machines, inspiring initial attempts to utilize cage rotor asynchronous motors for similar applications, [11].

The initial deployment of the dfig was evaluated, [12]. This implementation utilized a control technique incorporating a Proportional-Integral (PI) controller to trigger sinusoidal Pulse Width Modulation (PWM) with a consistent switching-frequency. Various researchers have widely adopted this control scheme. A thorough exploration of the dfig is suggested, incorporating the determination of rotor position from voltage and current parameters, [13].

A notable analysis was conducted with A. The matrix amalgamation, [14], of the DFIG and its performance in voltage dip. Additionally, contribution to the field with additional analysis of the transient model of DFIG done, [15]. Control strategy of a dfig, employing hysteresis controllers, to achieve optimal performance, [16].

The converters RSC, and GSC are analysed autonomously to investigate the dfig. The RSC can be executed autonomously, prior to a stable DC-potential, is supplied from the GSC. A grid-side controller with the capability to manage the DC potential amidst irregular source voltage situations were suggested, [17]. However, this configuration could not address imaginary power compensation.

The operational point of the GSC can be established based on the operational point of the RSC, and operational conditions of the generator. Introduced analysis sustained by non-linear voltages, [18], and slip regulators for a dfig tied to the grid. Explored a straight real, and imaginary power regulators relying on stator hurtle employing a hysteresis current controller, [19]. An exemplary vector governing mechanism to modulate the real, and quadrature powers generated from a dfig, [20], was devised. Fundamentally, a controller built upon a dfig is akin to the traditional AVR/PSS, [21]. This controller assists in upholding the frequency, and stoutness of the power system voltage.

The paper outlines a hypothetical implementation of a supervisory system configured for a wind generator relying on the dfig. The supervisory scheme employs field-based control for monitoring the RSC and utilizes a hysteresis modulator to regulate the GSC. A crucial and critical function of the dfig is to sustain the stable operational state of the DC potential.

The RSC approach facilitates, autonomous control over both real, and quadrature power in a dfig through the regulation of rotor-currents. The effectiveness of these control methods, is closely tied to the machine electrical attributes, and the transitions occurring within its reference structure.

Nonetheless, the field-oriented control approach, achieves outstanding control performance, demonstrating robustness, swift responses in both transient and steady states, and precision.

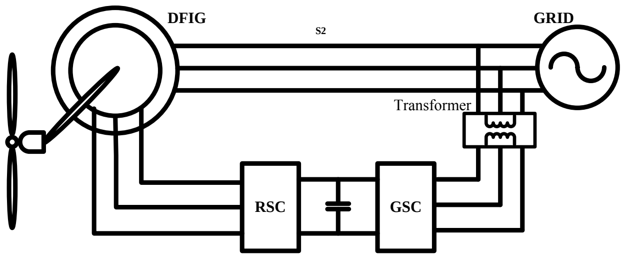

Fig. 1: Proposed configuration of DFIG system

The GSC propels the passage of power through the RSC, while offering supplementary quadrature power. Hysteresis control governs the GSC, maintaining a consistent DC potential, and ensuring sinusoidal current along the line. This paper explores production of power by employing, a dfig, and analyses the regulating characteristics of its GSC, and RSC through an active persistent approach. This study enhances the perception of a dfig associated wind-turbine application, below various regulating situations across extensive scale. The configuration of scheme of envisioned wind-turbine coupled DFIG system, is depicted in Figure 1.

2 Structure Model

2.1 Windturbine (WT)

A wind-turbine produces electric power, by capturing and, utilizing the energy from the wind to drive its coupled asynchronous generator. When the air currents pass across the blades of the turbine, it induces lift, and creates a rotational force. These blades spin the shaft located in the casing, this rotational force is then, linked to a gearbox. The gearbox amplifies, the revolving velocity of the coupled generator, and, subsequently, the generator utilizes a magnetic field, to transform kinetic form into electric power.

The power derived from wind is articulated, [22], as:

$$P_m = 0.5C_p(\lambda, \beta)\, \rho\, \pi r^2 v^3 \qquad (1)$$

In this context, "ρ" denotes the density of air; "r" denotes the turbine' ssword radius; "v" denotes the wind swiftness, and, "Cp" denotes the coefficient of power. The coefficient of power is contingent upon the tip swiftness ratio "λ" and the sword angle "β". The tip swiftness proportion is expressed by:

$$\lambda = \frac{\omega r}{v} \qquad (2)$$

Here, 'ω' represents the rotational speed of the generator.

From the equation (2), the tip swiftness ratio "λ", is altered, by regulating the swiftness "ω", thereby, controlling the "Cp", and the induced output-power, generated by wind turbines. The dfig is employed in configuring the wind turbines, enabling the adjustment of velocity to simulate varying wind velocities.

2.2 Modelling of DFIG

The DFIG is considered akin to the traditional generator, with a rotor emf. The formulation provided in [23], defines the expression for the3-ph DFIG is defined as:

$$v_{ds} = R_s i_{ds} - \omega_s \Psi_{qs} + \frac{d\Psi_{ds}}{dt} \qquad (3)$$

$$v_{qs} = R_s i_{qs} - \omega_s \Psi_{ds} + \frac{d\Psi_{qs}}{dt} \qquad (4)$$

$$v_{dr} = R_r i_{dr} - s\omega_s \Psi_{qr} + \frac{d\Psi_{dr}}{dt} \qquad (5)$$

$$v_{qr} = R_r i_{qr} - s\omega_s \Psi_{dr} + \frac{d\Psi_{qr}}{dt} \qquad (6)$$

$$\Psi_{ds} = L_s i_{ds} + L_m i_{dr} \qquad (7)$$

$$\Psi_{qs} = L_s i_{qs} + L_m i_{qr} \qquad (8)$$

$$\Psi_{dr} = L_r i_{dr} + L_m i_{ds} \qquad (9)$$

$$\Psi_{qr} = L_r i_{qr} + L_m i_{qs} \qquad (10)$$

On the other hand, 'ω_s' represents, the angular velocity within the coordinated reference frame.,$s\omega_s = (\omega_s - \omega_e)$ is the slip swiftness, and 's' is the slip,'ω_e'denotes the rotational velocity of that generator, linked to the kinetic velocity of the generator through the pair of pole number, as indicated$\omega_e = p/2\omega_r$ with $R_{s,}$ R_r, L_s *and* L_r are the resistance of stator, resistance of rotor, inductance of stator, and inductance of rotor respectively. $L_m$is the mutual-inductance, and $\omega_r$is the rotational velocity of the rotor. The expressed formula, the resulting electric torque from the dfig is expressed as follows.:

$$\begin{aligned} T_e &= \frac{3}{2}p(\Psi_{dr} i_{qs} - \Psi_{qr} i_{ds}) \\ &= \frac{3}{2}pL_m\,(i_{dr} i_{qs} - i_{qr} i_{ds}) \\ &= -\frac{3}{2}pL_m\,(i_{dr} i_{qs} - i_{qr} i_{ds}) \end{aligned} \qquad (11)$$

Here, 'p' signifies the count of pole pairs.

The interpretation of the real and responsive power of the stator as well as rotor for the dfig is denoted by:

$$P_s = \frac{3}{2}\,(v_{ds}i_{ds} + v_{qs}i_{qs}) \quad (12)$$

$$Q_s = \frac{3}{2}\,(v_{qs}i_{ds} - v_{ds}i_{qs}) \quad (13)$$

$$P_r = \frac{3}{2}\,(v_{dr}i_{dr} + v_{qr}i_{qr}) \quad (14)$$

$$Q_r = \frac{3}{2}\,(v_{qr}i_{dr} - v_{dr}i_{qr}) \quad (15)$$

The power loss linked to the rotor and stator resistances is not considered in this expression.

3 Control Techniques

The regulating scheme for the dfig, comprises both grid side, and rotor side controls. The real and imaginary powers are modulated by RSC, [24], and the DC link potential regulation as well as imaginary powers are instilled into the grid and regulated by GSC.

3.1 Control of Wind Turbine

Now-a-days WECS are much more popular in REs as they are abundantly available in nature. The unpredictable characteristics of wind and the varying hurtle operation in WECS, involves the use of Variable-Speed Wind Turbines (VSWT) in conjunction with dfig. The dfig is preferred for its primacies, like variable speed operation within a range of approximately± 30% of the nominal-speed, separation of real and receptive powers, enhanced energy conversion, and reasonable price. At the same time, DFIG has a few drawbacks, including the impact of changes in conditions and sudden changes in the wind stream. Due to this, the system's operating point is changed from the most economical point. Several control topologies are presented to enhance the performance of DFIG and VSWT. Traditional controllers like PI (proportional and integral) are implemented in the major research studies. Along with the PI controllers, MPPT techniques are implemented to harness utmost energy, from the wind. The working of VSWT near the speed at cut-in is described with the segments, [25].

Segment 1 (prior to A):
The speed of the wind breeze is below 4 m/s; it comes under this segment-1, and no power is extracted. The hurtle of rotor, is customised to the lowest value of the speed by implementing the regulator in the angle of the wind turbine blades below “cut-in speed “at point ‘A’. The operation of VSWT is considered halt-state and checks for any rise in wind speed.

Segment-2(A–B):
As the hurtle of wind, crosses the cut-in speed, mechanical strength emanates with the speed of the wind breeze, and the VSWT is now interfacing with the grid. As the wind blows at a lower value of the speed, the hurtle of the rotor is retained at a reduced speed. Therefore, the power coefficient ‘Cp’ is retained at its utmost point. The wind turbine cannot harvest a viable amount of power from the wind. In this condition, the tilt in pitch, is generally adjusted to zero degrees.

Segment-3(B–C):
MPPT functioning of VSWT MPPT can be obtained when the speed of the rotor is regulated in accordance with the wind breeze such that optimal TSR (opt)) is obtained, and the coefficient of power (Cp)) is achieved to it so maximum value The speed of the rotor changes, corresponding to the speed of the wind.

The controller, as depicted in Figure 2, enables the wind turbine to attain the optimal speed corresponding to the current wind speed. Various hurtles of wind breeze, different regulating techniques, are implemented to obtain the interrelation between electro-magnetic torque and the maximal power developed, and the corresponding optimal rotor speed is obtained.

Segment-4(C–D):
The hurtle of the rotor, approaches a specified nominal value of hurtle at the point "C" and maintains the specified value to eliminate huge instinctive hassle and noise at the VSWT. Consequently, the TSR is not at its finest value, and the Cp is less than the value from segment 3 (B-C). The VSWT sustains, the tilt in pitch, at its optimal value until the output power (mechanical) approaches the predefined nominal value.

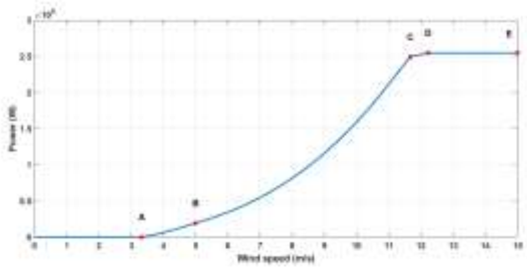

Fig. 2: Wind speed vs Wind turbine power

Segment-V(D-E)

When the wind speed surpasses 12 meters/sec, the mechanical output of the Variable-Speed Wind Turbine is adjusted to a predetermined nominal value. This is done to mitigate excess current in the converters (GSC and RSC) and prevent an overload on the entire drive system. This adjustment is achieved by controlling the pitch angle.

3.2 Rotor Side Controller

The dfig facilitates power output to both the stator, and rotor circuits of the machine. Employing such a machine enables the attainment of an elevated pf (power factor), even when the speed deviates slightly above the synchronous speed. Consequently, these generators can wield without the requirement for additional bypass-compensating equipment. The rotor current of the machine, is transformed into the dq component as follows. The current generates magnetic lines within the gap, that coincides the rotational force, to interact with the stator. These interactions produce constituents of the flux that is quadrature to the vector. The evolved torque results from the accumulation of the two vectors, and in this manner, the current contributes to the evolution of torque. This current regulates the receptive power entering the dfig. The precise orientation of the currents enables the regulation of the active and receptive power on the stator-side. The pivotal step involves determining the instantaneous stance of the rotating magnetic flux, in vector-space to establish the rotating reference frame. It is established through Lenz's law, which posits that the potential in the stator winding can be obtained from the stator flux links. Consequently, the stator potential and current undergo a 3-phase transformation, can be transformed into the 'αβ' reference frame. The stator winding flux in the αβ reference- frame is represented by:

$$\Psi_{\alpha\beta s} = \int v_{\alpha\beta s} - R_s i_{\alpha\beta s} dt = (\Psi_{\alpha s}, \Psi_{\beta s}) \quad (16)$$

To align the synchronously rotating dq reference frame with the stator field motion, information about the rate of change in stator flux can be derived from the following expression:

$$\Psi_s = |\Psi_{\alpha\beta s}| \, angle(\Psi_{\alpha\beta s}) \quad (17)$$

$$angle(\Psi_{\alpha\beta s}) = \theta_s = \tan^{-1}\left(\frac{\Psi_{\alpha s}}{\Psi_{\beta s}}\right); \; |\Psi_{\alpha\beta s}| = \sqrt{\Psi_{\alpha s}{}^2 + \Psi_{\beta s}{}^2} \quad (18)$$

This angle imparts the instantaneous stance of the revolving magnetic field in the stator. While the rotor is in motion, and momentarily oriented at a gradient, the stator magnetic field, with the mentioned frame fixed to the rotor, is referred to as the "slip angle". The reference frame is aligned to establish a simplified mode.

$$v_{qs} = \omega_s \Psi_{ds} = v_s; \; v_{ds} = 0 \quad (19)$$

The torque contingent on the "current i_{qr}" and its regulation is done by the "voltage v'_{qr}". The regulator assesses the "error" beneath the i_{dr} and $i_{qr}$and, the reference current $i_{dr-ref}$and i_{qr-ref}. This "error" is then subjected to PI regulator to procure counter balance voltages,$v'_{dr}$and v'_{qr}. To derive the appropriate reference voltage, the regulator outcome must be balanced with two decoupling labels.

$v_{dr-ref}$and v_{qr-ref}as below:

$$v_{dr-ref} = R_r i_{dr} + \sigma L_r \frac{di_{dr}}{dt} - \omega_{slip} \sigma L_r i_{qr} \quad (20)$$

$$v_{qr-ref} = R_r i_{qr} + \sigma L_r \frac{di_{qr}}{dt} - \omega_{slip}\left(\frac{L_m}{L_s}\Psi_{ds} + \sigma L_r i_{dr}\right) \quad (21)$$

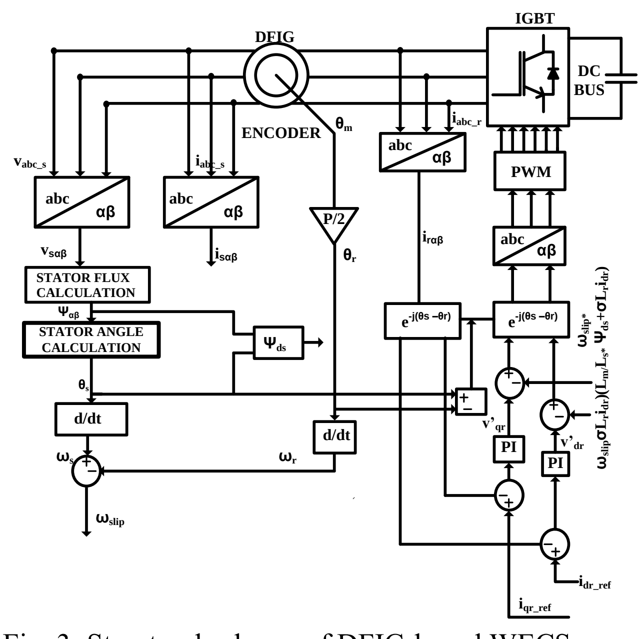

Fig. 3: Structural schema of DFIG-based WECS

In the control mechanism depicted in Figure 3, the currents in the rotor(i_{dr}, i_{qr}) constrainedand governed so that monitoring the corresponding references, i_{dr-ref} andi_{qr-ref}.With that frame coordinated with the stator flux, The q(quadrature)-current governs the true power and the d(direct)-current governs the receptive power. Therefore, the q(quadrature)-current is associated to generator electro mechanical torque, while the d(direct) current is associated with the voltage profile.

$$i_{dr-ref} = v_{qs}/\omega_s L_M \tag{22}$$

$$i_{qr-ref} = -2T_e L_s/(3PL_M^2 i_d^*) \tag{23}$$

The PWM regulator functions in the rotor circuit of the generator, and regulator is executed through signals of PWM affecting the rotor circuit current, the stator circuit current, the stator potential, and the stance of the rotor of dfig, [26].

3.3 Grid-side Controller

The predominant intent of the GSC is to retain a robust DC link potential, regardless of its amplitude and the direction of the power flow rotor. To achieve that, a hysteresis modulator within the reference framework, oriented with the stator potential instance, is employed, as illustrated in Figure 2. It confesses for flexible regulation of the DC potential and receptive power between the grid, and the converter.

The power source is restricted by the RSC, typically generated by employing a Voltage Source Converter (VSC) tied-up with the grid, specifically on the stator side of the dfig. A capacitor is employed to mitigate fluctuations and maintain the DC potential at a relatively consistent level. A “PWM” converter is employed to perpetuate the constant DC link potential. The GSC fulfils the real power requirements as dictated by the RSC. Operation with the converter employing reference flow scheme is facilitated, and consequently, hysteresis control is adopted. In this control scheme, the discrepancy between expected and measured currents is employed to regulate the output potential of the conventional sine PWM converter, ensuring the desired power factor, [27]. The architecture of the GSC is illustrated in Figure 4.

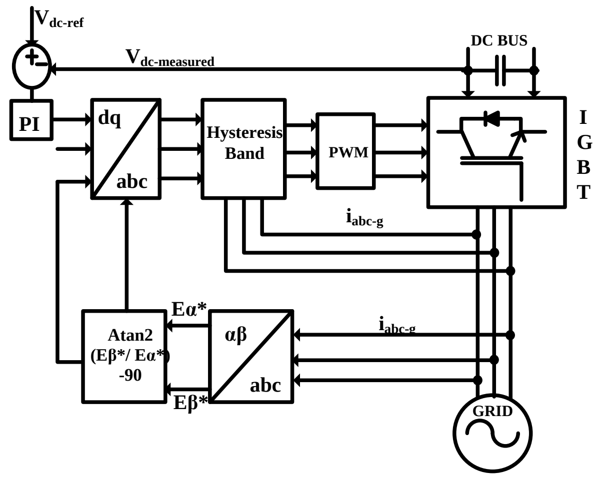

Fig. 4: Schematic diagram of GSC

The voltages on the grid side in the dq reference frame are expressed as follows:

$$v_d = Ri_d + L\frac{di_d}{dt} - L\,\omega\, i_q + v_{dl} \tag{24}$$

$$v_q = Ri_q + L\frac{di_q}{dt} - L\,\omega\, i_d + v_{ql} \tag{25}$$

Where v_d, v_q are the grid emfs in the d-q frame,v_{dl},$v_{ql}$are the GSC emfs in dq frame.,i_d, i_q are the grid side dq currents, R and L represent the filter resistance and inductance, respectively, while 'ω' denotes the rotational recurrence. The true, and receptive powers are stated by:

$$P = 3(v_d i_d + v_q i_q) \tag{26}$$

$$Q = 3(v_d i_q - v_q i_d) \tag{27}$$

The stance of that grid emf is derived by:

$$\theta_e = \int \omega_e \, dt = \tan^{-1}\left(\frac{v_\beta}{v_\alpha}\right) \tag{28}$$

Here “v_α", and "v_β "are ‘α’ and ‘β’coordinates in the grid emf, organised by dq emfs v_d making $v_q = 0$. Indeed, as the grid emf maintains a steady amplitude,v_d will also have a steady amplitude.

3.4 Control of DC Link Voltage

The error potential is expressed as:

$$e = v_{dc-ref} - v_{dc} \tag{29}$$

It’s deviation, is given by:

$$\Delta e = (1 - z^{-1}) \tag{30}$$

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$$v_{dc} i_{os} = 3 v_d i_d \tag{30}$$

The currents the DC busv_{dc}in the vector aligned allusion frame. Therefore, the reference currenti_{dref} is procured from the DC-tied potential blunder Δe and its digression are tuned by the gains of PI controller. To attain a power factor, close to unity at GSC converter, receptive power value should be zero, hencei_{qref} =0. Following the dq-to-abc conversion of the reference current, a hysteresis regulating scheme can be implemented.

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4 Emulation of VSWT-DFIG

The emulated system comprises a dual excited asynchronous generator propelled with VSWT. This generator is accompanied by a back-to-back connected RSC and a GSC, connected to the grid through a transformer. The true and receptive power, extracted with VSWT-DFIG, is controlled with rotor currents in the RSC. Appropriate electric power transmission is achieved by governing the DC link potential, which is further modulated with a GSC.

4.1 Control of Power with i_{dr}, i_{qr}

The wind turbine driven dfig is emulated for (0-7) sec. Below the synchronous speed, the wind turbine swiftness is maintained for up to 3 seconds. As illustrated in Figure 5, the wind turbine operates at synchronous speed for up to 5 seconds and at hyper-synchronous speed for up to 7 seconds.

To modulate the powers (true and receptive), the rotor current components, i_{dr} and i_{qr} are regulated by tracking the references i_{dr-ref} and i_{qr-ref} respectively. The reference tracking is achieved successfully shown in Figure 6.

Inferred from Figure 7 is the regulation of real and reactive power by adjusting the d-axis current of the rotor (i_{dr}). The rotor current response under different speeds is shown in Figure 8.

It is perceived that the true power is modulated by regulating the i_{qr} (q-quadrature current of rotor) to track the reference current i_{qr-ref}, the true power is controlled.

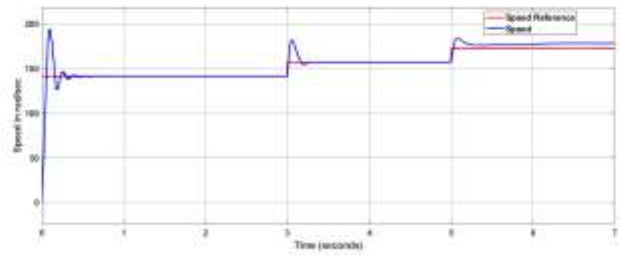
Fig. 5: Rotor Speed characteristics

Similarly, the receptive power is augmented to maintain power equilibrium with the grid. The corresponding responses of true power with rotor q-quadrature current, and receptive power with rotor d-axis current is depicted in Figure 9 and Figure 10.

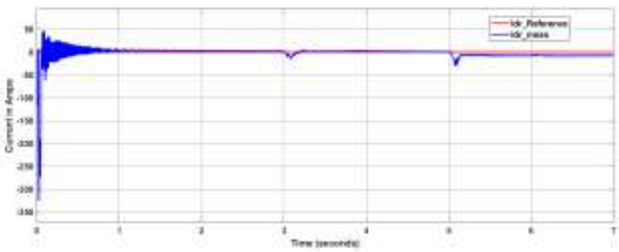
Fig. 6: Output of the d-axis rotor current (Idr)

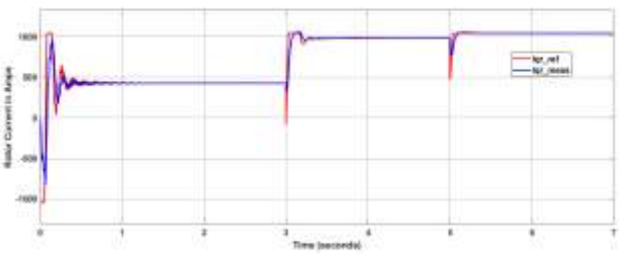
Fig. 7: The output of Rotor q-current (Iqr)

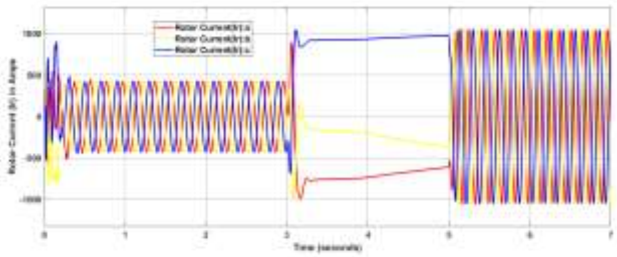
Fig. 8: Rotor current Response (Ir)

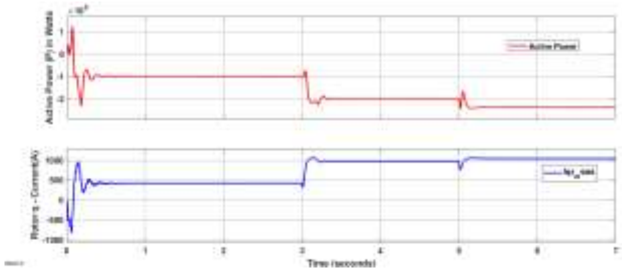
Fig. 9: Output of True power with Iqr

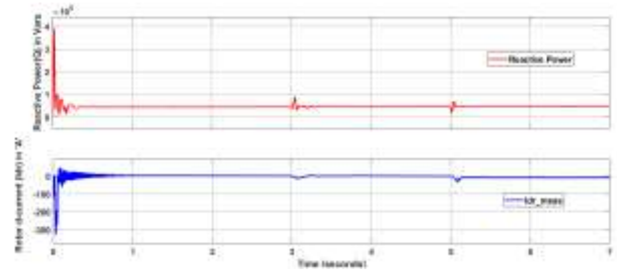
Fig. 10: Imaginary power variation with Idr

4.2 Effect of the DC-Link Potential

True power reduces as receptive power increases to compensate for the total power. Furthermore, a proportional-integral (PI) controller is employed to precisely modulate the DC-link potential, ensuring it tracks a constant reference as depicted in Figure 9.

To inject true power into the rotor through RSC, it is essential to retain the DC-link potential as stable as possible. To track that DC reference potential, a robust PI regulator is implemented. Regulating the d-q components of the grid current allows for attaining a flat voltage profile from the GSC. The DC link potential profile is depicted in Figure 11.

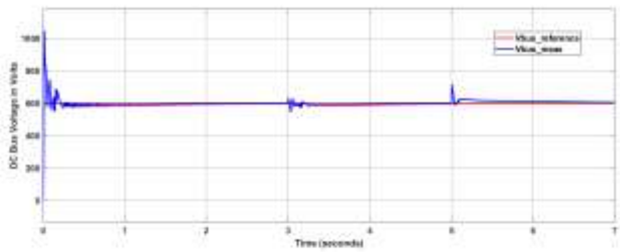

Fig. 11: Response DC link Voltage

4.3 Impact of Rotor Speed on the Rotor Currentsi_{dr},i_{qr}

As the wind swiftness is changing continuously, the variations are emulated by considering different values of wind speeds. In the wind swiftness range of 8 m/s to 11 m/s, the rotor speed remains in sub-synchronous range for 1 to 3 seconds. During wind swiftness ranging from 11 m/s to 12 m/s, the rotor speed attaining synchronous speed for a duration of 3 to 5 seconds. In wind speeds ranging from 12 m/s to 15 m/s, the rotor speed surpasses synchronous speed, achieving super-synchronous speed for a duration of 5 to 7 seconds. The rotor speed is tracked by implementing a robust PI regulator.

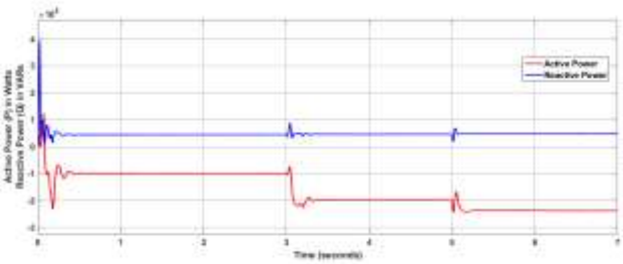

Fig. 12: Output of True and Imaginary Powers

Figure 12 shows the true and imaginary power curves of the DFIG Machine. The d-component current is robustly controlled and remains unaffected by variations in rotor swiftness. Only the rotor q-component current is transformed by the rotor turtle. The modulated true, and receptive power is achieved by modulating the rotor “d-q” currents. Hence RSC is employed to modulate the power with tracking the rotor, and currents. The true power response is depicted in Figure 9. The DFIG machine related all parameters are depicted in Table 1(Appendix).

5 Conclusion

In this paper, control schemes for true, and imaginary powers are explored in a fluctuating wind turbine-coupled DFIG. The emulated model covers sub-synchronous, synchronous, and hyper-synchronous speeds. The configuration of tandem(back-to-back) connected RSC and GSC, direct current control techniques, real and receptive power modulation, dc link potential regulation with the help of GSC, and speed control techniques are implemented and validated at different wind speeds with simulations.

Further investigation can be enhanced to implement advanced controllers, providing filters to reduce harmonic distortion.

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APPENDIX

Table 1. DFIG machine parameters

Power	250KW
Stator Voltage	400V
Stator Current	400V
Rotor Voltage	370A
Poles pair	2
Frequency	50
Rotor speed	1500 rpm
Bus Voltage	600V

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