

A Fuzzy based Synchronous Flux Weakening Control with Flux Linkage Prediction for Doubly-Fed Wind Power Generation Systems

M. Rama Sekhara Reddy, M. Vijaya Kumar, M. Mahesh

Abstract: With the expanding joining of DFIG based substantial breeze power plants, their effects on power regime inert and potent conduct must be examined. Amid grate voltage douses, it consists of DC;-ve succession parts within rotor and stator transition and ephemeral high current are created. Thus to conquer this, a concurrent motion debilitate manage regime with motion liaison forecast is proposed. In conventional manage, the bum prescient manage was exerted to realize fast synchronization and frail collaboration among rotor and stator transition by motion liaison expectation under grate voltage plunges. In advanced manage methodology a FLC is exerted to conquer every one of issues happened in conventional technique. The outcome denote thus advanced manage regime is viable in stifling high current in stator and rotor and decreasing motions in torsion, with to a great extent enhances the execution of DFIG amid grate voltage douses

Keywords: Rotor Side Converter (RSC), Grid Side Converter (GSC), Low Voltage Ride through (UVRT), Electromagnetic Theory (EMT).

I. INTRODUCTION

As of late, broad scrutiny was centered around breeze energy production [1,2]. WT considering dually-encouraged acceptance alternator are universally received in the breeze showcase because for VSCF capacity, brilliant accelerate ordinance execution [3-5]. But, the power converter with little limit isn't helpful for UVRT. For DFIG, the limit of power converter is just 0.3 as of alternator, dwindle the expense of method. The manage of DFIG comprehended by PWM converter i.e straightforwardly concomitant with rotor. It is awesome manage dispute for the future progress of DFIG amid grate voltage douses. DFIG is exceptionally delicate to grate unsettling influence particularly to grate douses as stator windings are specifically concomitant with grate. Because of little limit and frail manage capacity of PWM converter, the concealment of flaw high current is constrained. Presently, a conceivable method to upgrade the UVRT capacity is establishment of a lever over rotor extremities. If is lessened and UVRT amid grate douses is executed [6,7]. Be that as it may, a lot of reactive power is devoured from grate as the DFIG carries on as universal acceptance alternator, prompting advance debasement of grate flaws [8]. Furthermore [10], the equipment price was expanded. Amid grate VD, the alternator was layout in +ve and -ve concurrent allusion outline. As denoted by the distinction of manage goals, +ve, -ve succession

deterioration of factors is led and extent basic (PI) controllers are advanced in the manage, which influences the vigorous execution and the reaction of method. By swapping the relative, basic quotients of PI controller, the UVRT ability is enhanced inside a specific range.

Despite, very well may be just connected to same treble-stage grate vtg flaw. The alternators are managed to balance bothersome impact of DC ephemeral segment in stator transition liaison, debilitating the impact on rotor and accomplishing UVRT. It is shown that supply - impudent ephemeral current manage methodology is plausible to dwindle the flood of ephemeral high current on the DFIG[13]. The immediate AP and RP of stator is examined and two resounding manageress are applied for accomplish full manage of o/p power and enhance the robustness of manage method. During uneven douses, it has no compelling reason to separate the +ve, -ve succession segments. It contains a straightforward shape and decreases changes in EMT and power.

In prescient current manage methodology, the vigorous reaction of manage regime can be enhanced. The mangier has a quick reaction to flaw and the flaw current can be stifled rapidly. Sliding mode manage is advanced for DFIG, compelling in dwindling motions of RP and EMT [17,18]. A concurrent transition debilitating manage technique with motion liaison expectation is assisted for DFIG. Amid grate voltage drops, the manage regime is exchanged and the promoted manage procedure is applied. It takes the dead beat manage methodology joined with a debilitating transition manage of DFIG. In typical operation, a relative resounding (PR) manage procedure in view of double-stage unfluctuating allusion outline is connected to streamline facilitates change. Right instanter, the ephemeral variety of rotor and stator transition is explored amid grate flaws. At that point, to get the ideal allusion rotor transition, the connection between stator motion and rotor motion is concluded in double-stage unfluctuating allusion outline. Right now of flaw, with the quick expectation and brisk reaction of bum controllers, stator motion can be followed by rotor transition quickly, which dispenses with the effect of stator motion on rotor motion and debilitates the flaw current stun of rotor and stator. More stead EMT is comprehended and the UVRT ability of DFIG is enhanced. As of late, FLCs have produced a decent arrangement of enthusiasm for specific applications. The idea of sort 2 fuzzy sets was first presented by Zadeh as an expansion of

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idea of surely understood common fuzzy sets, fuzzy sets.

II. PROPOSED DFIG MODEL

The square graph of proposed system is shown .DFIG Stator is straightforwardly concomitant with grate while rotor is energized by the twofold PWM consecutive converters to guarantee solipsistic energy stream

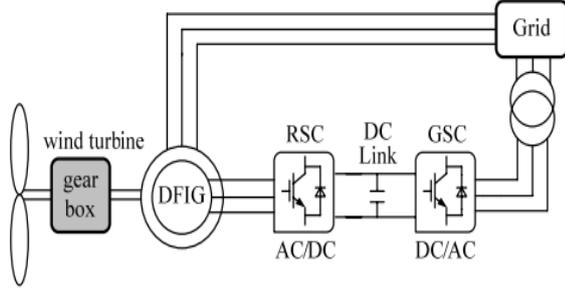


Fig. 1: Square graph of DFIG.

From Fig. 1, twofold PWM consecutive converters comprise of GSC and RSC. The RSC is concomitant with rotor to direct reactive and active power at unfluctuating side while the GSC is concomitant with grate by transformer to accomplish power criticism to grate and to guarantee solidarity PF. Fig. 2 is proportionate circuit of DFIG in double-stage unfluctuating allusion outline. Scientific condition voltage of rotor and stator and motion for proposed model in the double-stage unfluctuating allusion edge is portrayed as

$$\begin{cases} U_{s\alpha\beta} = R_s I_{s\alpha\beta} + p\varphi_{s\alpha\beta} \\ U_{r\alpha\beta} = R_r I_{r\alpha\beta} + p\varphi_{r\alpha\beta} - j\omega_r \varphi_{r\alpha\beta} \end{cases} \quad (1)$$

$$\begin{cases} \varphi_{s\alpha\beta} = L_s I_{s\alpha\beta} + L_m I_{r\alpha\beta} \\ \varphi_{r\alpha\beta} = L_m I_{s\alpha\beta} + L_r I_{r\alpha\beta} \end{cases} \quad (2)$$

where , ω_r is gaunt speed of rotor and p is distinction operator , $U_{s\alpha\beta}$ and $U_{r\alpha\beta}$ are the voltages of rotor and stator, R_s and R_r are rotor and stator opposition, $I_{s\alpha\beta}$ and $I_{r\alpha\beta}$ are currents of rotor and stator, $\Psi_{s\alpha\beta}$ and $\Psi_{r\alpha\beta}$ are stator and rotor motion. L_s , L_r and L_m , are the individual-inductances of rotor and stator

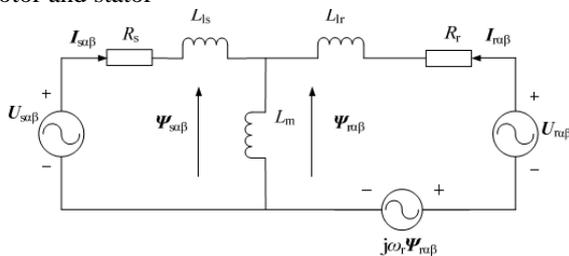


Fig.2: Equivalent circuit in a double-phase unfluctuating allusion frame.

The quick reactive and active power o/p from stator to grate is communicated,

$$\text{as } \begin{cases} P_s = -3/2(u_{s\alpha} i_{s\alpha} + u_{s\beta} i_{s\beta}) \\ Q_s = -3/2(u_{s\beta} i_{s\alpha} - u_{s\alpha} i_{s\beta}) \end{cases} \quad (3)$$

$I_{s\alpha}$ and $I_{s\beta}$ are stator current, $u_{s\alpha}$ and $u_{s\beta}$ are β -hub and α -pivot segments of vtg of stator reactive and active power.

The EMT of proposed model is depicted as

$$T_e = n_p L_m (i_{s\beta} \varphi_{s\alpha} - i_{s\alpha} \varphi_{s\beta}) \quad (4)$$

Where T_e remains for the electromagnetic torque, n_p is quantity of shaft sets; $\Psi_{s\alpha}$ and $\Psi_{s\beta}$ are β -hub and α -pivot segments of stator motion in the $\alpha\beta$ allusion outline,

separately. As of (1) and (2), rotor vtg of DFIG can be additionally communicated as

$$U_{r\alpha\beta} = (R_r - j\omega_r \sigma L_r) I_{r\alpha\beta} + \sigma L_r p I_{r\alpha\beta} + \frac{L_m (U_{s\alpha\beta} - R_s I_{s\alpha\beta} - j\omega_r \varphi_{s\alpha\beta})}{L_s} \quad (5)$$

Under typical method, the β -pivot and α -hub the parts of I of rotor is managed by the PR mangier in the dually-stage unfluctuating allusion outline. As denoted by the PR manage procedure, voltage of rotor can be outlined as

$$U_{r\alpha\beta}^* = \sigma L_r U_{r\alpha\beta}' + (R_r - j\omega_r \sigma L_r) I_{r\alpha\beta}' + \frac{L_m (U_{s\alpha\beta}' - R_s I_{s\alpha\beta}' - j\omega_r \varphi_{s\alpha\beta}')}{L_s} \quad (6)$$

$$U_{r\alpha\beta}' = C_{PR}(s) (I_{r\alpha\beta}' - I_{r\alpha\beta}) = \left[k_{ip} + \frac{\omega_{ic} k_{ir} s}{s^2 + 2\omega_{ic} s + \omega_{ic}^2} \right] (I_{r\alpha\beta}' - I_{r\alpha\beta}) \quad (7)$$

III. MANAGE STRATEGY OF CONCURRENT FLUX WEAKENING

3.1. Trademark investigation under grate voltage douses

Below figure demonstrates the attractive ckt of rotor and stator for under the ordinary act and grate douses individually.

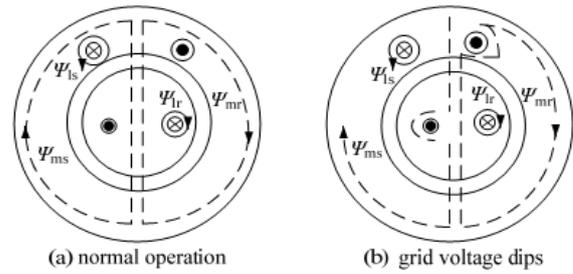


Fig. 3: Rotor and stator magnetic circuit

It tends to seen from Fig. 3 is attractive circuit changes if there should arise an occurrence of grate douses. In ordinary operation, the armature attractive field Ψ_{ms} and attractive field excitation Ψ_{mr} come over the air hole through the fundamental attractive ckt and stator is joined with rotor wndngs. During grate douses, Ψ_{ms} comes over rotor attractive spillage circuits without intersection rotor windings and Ψ_{mr} comes over stator attractive spillage circuits without intersection stator wndngs. Despite, ephemeral change in rotor and stator motion will give over ephemeral current. A bigger flaw current happens in rotor. The individual-inductance of rotor and stator is reliant on the attractive circuit in rotor and stator windings, which additionally influences stator and rotor transition. In state of grate vltage douses, stator vltage sags thusly cause -ve succession segments and ephemeral DC show up in stator motion. Stator motion in the double-stage unfluctuating allusion edge can be portrayed as

$$\varphi_{s\alpha\beta}(t) = \varphi_{s\alpha\beta+}(t) + \varphi_{s\alpha\beta DC}(t) + \varphi_{s\alpha\beta-}(t) = |\varphi_{s\alpha\beta+}| e^{j(\omega_s t + \varphi_+)} + |\varphi_{s\alpha\beta DC}| e^{-t/\tau_s} + |\varphi_{s\alpha\beta-}| e^{-j(\omega_s t + \varphi_-)} \quad (8)$$

Where unfluctuating $\alpha\beta$ axis, +ve succession segment, -ve succession part , DC segment, $\alpha\beta$, +, -, DC speak to stator transition separately; τ_s remains for weakening constant of DC segment; φ_- and φ_+ remain for the underlying stage points of +ve , -ve succession segment of stator motion.

3.2. The Manage Approach

Solid connection exists between rotor and stator, the -ve succession segments and DC in stator motion prompt high current in rotor.



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What's more, rotor opposition additionally changes with the temperature of alternator. Rotor motion and the opposition would then be able to be acquired as

$$\begin{cases} \varphi_{r\alpha}^m = a \times \varphi_{r\alpha} \\ R_r^m = b \times R_r \end{cases} \quad (20)$$

where m signifies the denotation in the bum prescient manage. As per qualities of L , opposition of alternator, motion and obstruction diverts to a specific degree. for miscreant prescient manage, the manage execution is firmly identified with the distinction betwn rotor motion at kth examining time and (k+1)th inspecting time. Along these lines, cis included and rotor vltage α -hub can be portrayed as

$$u_{r\alpha}(k) = R_r^m i_{r\alpha}(k) + \frac{c}{T_s} [\varphi_{r\alpha}^m(k+1) - \varphi_{r\alpha}^m(k)] \quad (21)$$

Substituting (21) in (17), it can be obtained as

$$\begin{aligned} \varphi_{r\alpha}(k+1) - (1 - a \times c) \varphi_{r\alpha}(k) \\ = a \times c \times \varphi_{r\alpha}^m(k+1) - (1 - b) \times R_r \times i_{r\alpha}(k) \times T_s \end{aligned} \quad (22)$$

From (22), second term at privilege of condition is little is ignored. The discrete exchange capacity of (21) is

$$\frac{\varphi_{r\alpha}(z)}{\varphi_{r\alpha}^m(z)} = \frac{a \times c \times z}{z - (1 - a \times c)} \quad (23)$$

As of (18) , (23) is stable only when a and c satisfy $0 < a \times c < 2$ (24)

Rotor transition is inside a specific scope of mistake and a steady dead beat manage regime is achieved. 6 figure demonstrates the connection between trademark roots Qz of (23) and a, c. At the point when the terms change, the extent of trademark is analyzed to decide the dependability of method. The outcome demonstrates that the regime is steady. At the point when factors c and a change, the trademark roots Qz

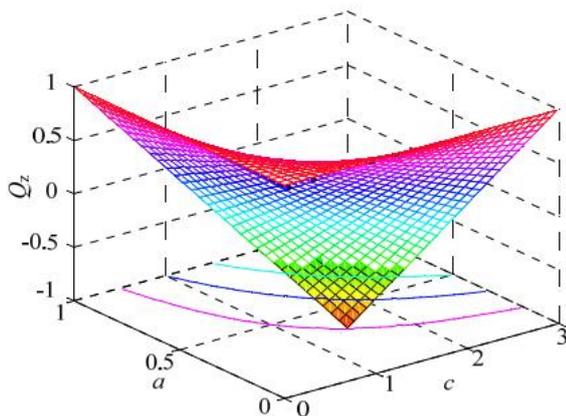
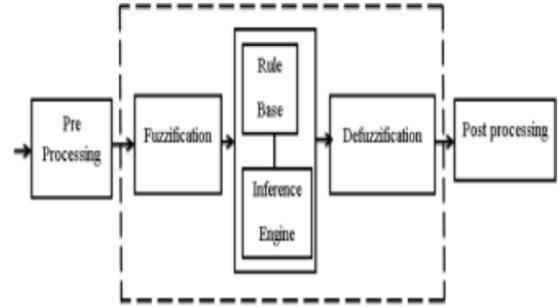


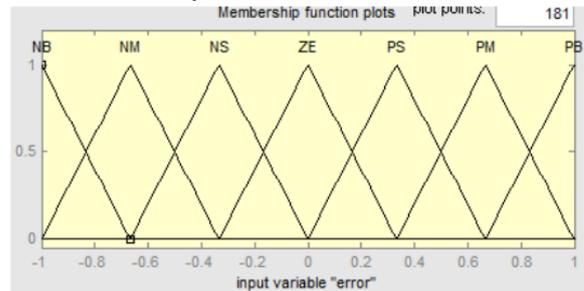
Figure 6: Constancy scrutiny

IV. FUZZY LOGIC

As of late, number furthermore assortment of uses of fuzzy rationale has expanded fundamentally. Applications go commencing shopper items, in as much as example, cameras, camcorders, clothes washers, furthermore microwaves to modern process control, medicinal instrumentation. In fuzzy Logic Toolbox programming, fuzzy rationale ought to be translated as FL, that is, fuzzy rationale in its wide sense. Essential thoughts hidden FL are clarified obviously furthermore shrewdly in Foundations of Fuzzy Logic.



FLT gives GUIs to give you a chance to perform traditional fuzzy scaffold improvement furthermore example acknowledgment. Utilizing tool stash, you can create furthermore dissect fuzzy induction scaffolds, create versatile neuro fuzzy surmising scaffolds, furthermore perform fuzzy bunching. Furthermore, tool compartment gives a fuzzy organizer hinder that you can use in Simulink to show furthermore reproduce a fuzzy rationale organize scaffold. Commencing Simulink, you can create C code in as much as use in installed applications that incorporate fuzzy rationale. . Keeping in mind end goal to organize these parameters, they are detected furthermore contrasted furthermore reference esteems. To accomplish this, participation elements of FC are: mistake, change in blunder furthermore yield.



V. OUTPUTS DISCOURSE

The correlations are completed between bum prescient manage technique and the advanced strategy. In addition, the encouraged manage methodology; the execution of DFIG with 01.50-MW is explored under grate vltage douses. The main data of DFIG regime are in Table.

Table 1: The main parameters of the DFIG

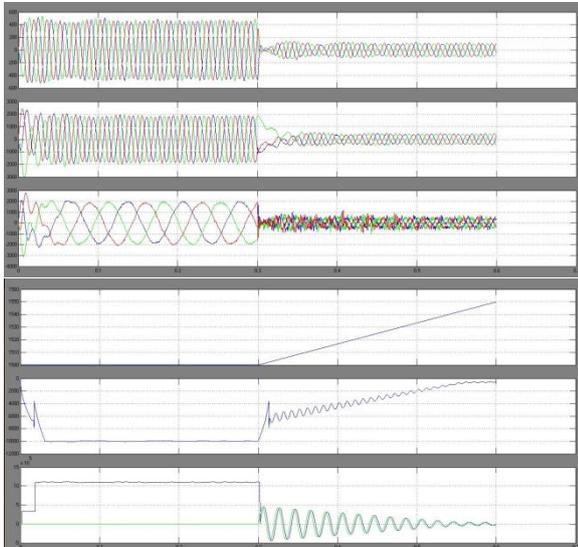
Parameters	Value
Rated generator power	1.5MW
Rated generator voltage	575V
Frequency	60Hz
Stator resistance	0.0014Ω
Stator leakage inductance	8.998×10^{-5} H
Rotor resistance	9.9187×10^{-4} Ω
Rotor leakage inductance	8.2088×10^{-5} H
Magnetizing inductance	1.526×10^{-3} H
Pole pairs	3

At point when a 0.8 equal douses happens at co succession of $t=3/10$ s, 7 figure demonstrates execution of DFIG worked with bum prescient manage procedure and facilitated manage technique separately.



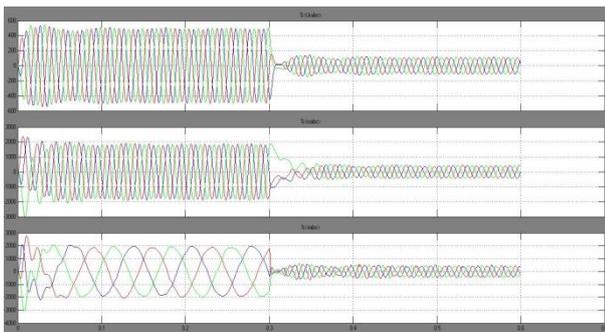
Contrasted and 7(a), it very well may be seen that the facilitated manage technique is more compelling than the killjoy prescient strategy when connected to wipe out rotor and stator high currents and decrease motions of EMT . In 7 figure (b), EMT vacillates in region of 0 and effect of automatic regime lessened; it improves the UVRT capacity of DFIG during grate douses. Stator and If s are manage led to be inside their most extreme permitted.

Conventional Manage Approach

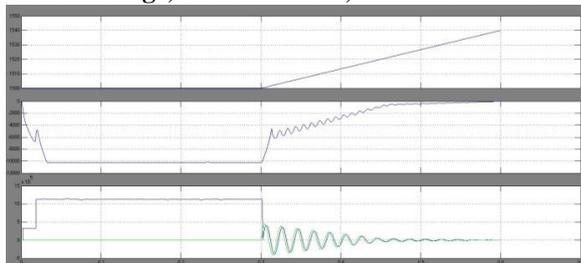


(a) Voltage, Stator current, Rotor current of DFIG
 (b) Speed, Torque, Power characteristics of DFIG

Proposed Manage Strategy



(a) Stator voltage, Stator current, Rotor current of DFIG



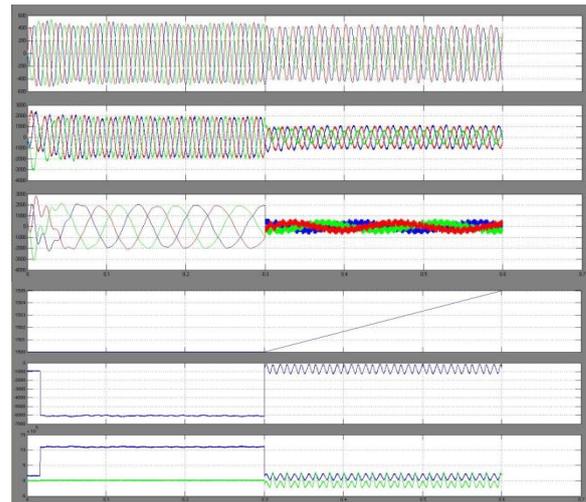
(b) Speed, Torque, Power characteristics of DFIG

Figure 7: outputs for a 0.8 symmetrical douses.

At the point when a 0.6 single-stage douses happens at co succession of $t=3/10$ s Looking at. 8(b) and 8(a), it is seen that variance of EMT is littler when utilizing the encouraged manage procedure which dwindles the automatic weight on the turbine method, 8 figure demonstrates execution of DFIG worked with dead beat manage methodology and with assisted manage technique individually. If is successfully smothered because of frail connection between stator and rotor transition. Moreover, stator AP varies around 0 and its

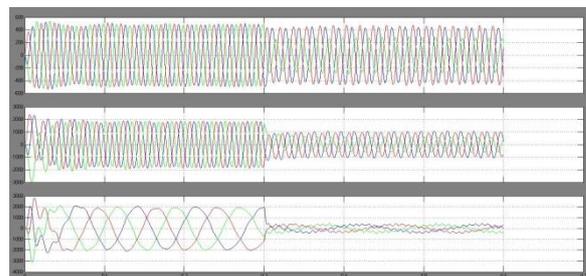
effect on grate is dwindle ed. To confirm the adequacy of promoted manage procedure, In 9(a), the EMT has a huge variance when uneven douses moves to symmetrical douses.9 FIGURE demonstrates the vigorous reactions of DFIG regime with dead beat manage technique and with promoted manage procedure amid various grate douses separately. A 0.6 single-stage douses happens at co succession of $t=1/5$ s and a 0.8 symmetrical douses happens at the co succession of $t=2/5$ s Additionally, rotor and stator flow currents are additionally expanded which prompts the RSC. The changes of stator RP and AP are as yet self-evident. Nonetheless, in 9(b), EMT has a littler vacillation when awry douses changes to symmetrical douses. Moreover, stator RP and AP winds up littler which guarantee execution of grate.

Conventional Manage Strategy

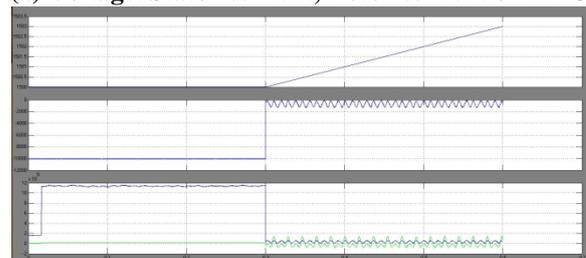


(a) Voltage, Stator current, Rotor current of DFIG
 (b) Speed, Torque, Power characteristics of DFIG

Proposed Manage Strategy



(a) Voltage, Stator current, Rotor current of DFIG



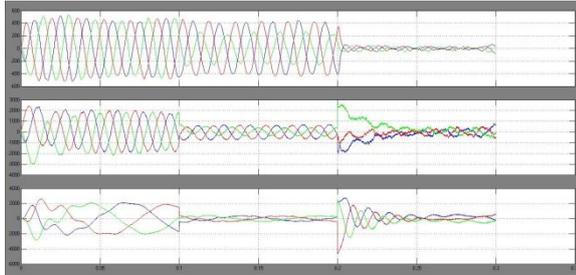
(b) Speed, Torque, Power characteristics of DFIG

Figure 8: outputs for a 0.6 single-phase douses

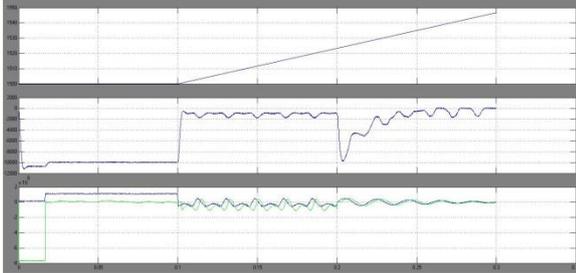


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Conventional Manage Strategy

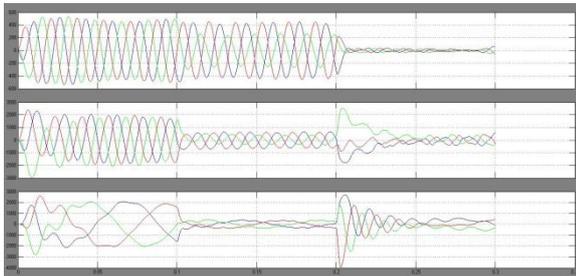


(a) Voltage, Stator current, Rotor current of DFIG

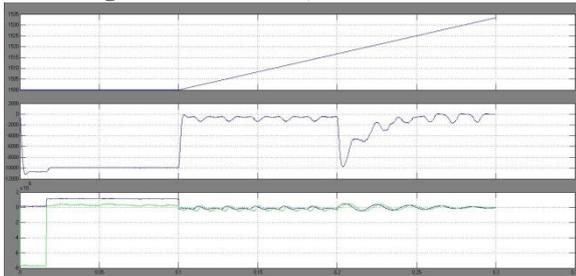


(b) Speed, Torque, Power characteristics of DFIG

Proposed Manage Strategy



(a) Voltage, Stator current, Rotor current of DFIG



(b) Speed, Torque, Power characteristics of DFIG

Figure 9: outputs for multiple douses.

N_d is level of symmetrical three-stage grate voltage douses, sister slip proportion of DFIG, $I_{r,max}$ is greatest estimation of I_r . 10 figure demonstrates most extreme rotor douses currents during the state of various grate voltage douses.

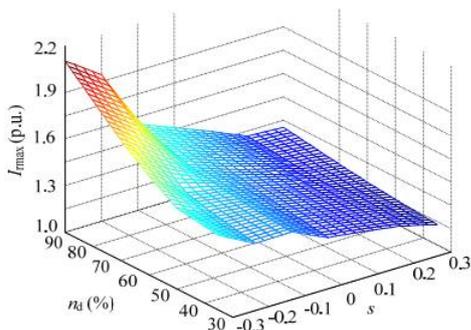


Figure 10: Most extreme rotor douses current during various working circumstance.

From figure 10, akin slip proportion, when the symmetrical douses differ from 30% to 80%, If is mangled inside the twice of most extreme current. Meantime, for akin drops, when the DFIG is worked at various slip proportions, Along these lines, the advanced manage technique has enhanced UVRT capacity. If is mangled to be inside the twice of greatest current.

VI. CONCLUSION

During, a concurrent transition debilitating manage with motion liaison forecast is assisted for dually-bolstered wind energy production modes. In states of similar and deviated douses, the FLC is connected with a specific end goal to know concurrent transition debilitating manage of rotor and stator motion rapidly. It smothers the high current caused by the cooperation between rotor and stator, enhancing the steadiness edge and UVRT capacity under grate douses. The outcome demonstrate that the assisted manage procedure has a few points of interest: 1) when a 0.8 similar douses or a 0.6 single-stage douses happens, in addition, including numerous douses, the I_s and I_r can be managed to be inside the twice of most extreme present, debilitating the effect on the ephemeral high current of breeze power method 2); It is powerful in taking outcome of stator motion on rotor motion, with a littler change in EMT and decreasing automatic stun of grate douses on alternator.; 3) basic in the manage structure and is anything but difficult to execute.

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