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CONTROL OF DFIG WIND POWER GENERATORS IN UNSTABLE MICROGRIDS FOUNDED ON INSTANT POWER THEORY

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ABSTRACT

The principle point of this paper is control methodology for a doubly-nourished enlistment generator (DFIG) wind vitality framework in an uneven microgrid dependent on momentary power hypothesis with type-2 fuzzy controller. In this task DFIG had been broadly used as a wind turbine generator, due its different preferences particularly low generation cost so it turns into the most essential and promising sources of sustainable power source. This paper introduces new control approach for a doubly-encouraged acceptance generator (DFIG) wind vitality framework in an uneven smaller scale matrix dependent on type-2 fuzzy controller. The proposed type-2 fuzzy controller utilizes immediate active/reactive power components as the framework state factors. This work focuses on studying of utilizing DFIG as a wind turbine associated with a small scale framework exposed to unbalanced loads. Moreover the control of active/reactive, the controllers utilizes the rotor-side converter for moderating the torque and reactive power pulsations. The control scheme also utilizes the framework side converter for partial compensation of unbalanced stator voltage. The primary features of the proposed control technique are its input factors are independent of reference frame transformations and it does not require sequential decomposition of current components. These features simplify the structure of required controllers under an unequal voltage condition and inherently enhance the robustness of the controllers. The execution of the proposed procedure in mitigating torque ripples and unbalanced stator voltage is examined dependent on the time-area simulation of a DFIG study framework under unequal grid voltage. Extension simulation considers are conducted to compare the response of the given framework with the type-2 fuzzy controller to the response given with the proposed plan.

Key terms: Doubly-Fed Induction Generator, Instantaneous Power, Micro Grids, Unbalanced Grid Voltage, Wind Energy, type-2 fuzzy controller.

I.INTRODUCTION

Wind control generation industry has ended up being commonly used over the latest couple of years and takes more thought of manufactures. There are various clarifications behind adding more breeze imperativeness to the electric frameworks. For instance, wind age is maintained by not only being unblemished and manageable yet what's more having inconsequential running cost necessities. Variable speed wind turbine topologies consolidate a wide scope of generator/converter courses of action, in perspective of cost, capability, yearly imperativeness getting, and control complexity of the general system. In view of the fast redesign and progression in make of force electronic converter advancement and the enhancement of acknowledgment machines uncommonly Twofold Nourished Enlistment Generators and its inclinations of little limit of converters, high essentialness and versatile power control, DFIG has been comprehensively used for broad scale wind control age systems on account of its distinctive focal points, for instance, factor speed movement, controllable power factor and upgraded structure capability. The proportion of essentialness expelled from the breeze relies upon the event turn speed, and on the control structure associated on the breeze imperativeness change system. The DFIG is equipped with a successive power electronic converter, which can adjust the generator speed with the combination of wind speed. The converter is related with the rotor windings, which goes about as cooling excitation system. Wind turbines began to contribute and increase tenaciously in electric power age in electric frameworks. Doubly-continued acknowledgment generators (DFIGs) in high-control wind turbine-generators (WTGs) are operational as passed on generators (DGs) units in littler scale systems. Continuous structure codes require a WTG remains operational in the midst of transient and steady state uneven system voltages [1], [2].

A voltage unbalance can tenaciously exist in a scaled down scale grid in light of unequal impedance of scattering lines; nonlinear burdens, for instance, twist warmers; and unequal apportionments of single-arrange loads. Shahnia et al. in [3] propose a passed on shrewd private load trade plan to dynamically diminish voltage unbalance along low voltage allotment feeders. In any case, as a result of using comprehensively passed on and variable burdens, for instance, single-arrange motors, and nonlinear loads in a little scale network, the voltage unbalance condition can't be completely directed. Of course, even a little proportion of voltage unbalance can cause amazing current unbalance in a DFIG. This present unbalance causes torque throbs and overheating of the machine windings which over the long haul reduce the lifetime of a DFIG-based WTG in a little scale cross section [4]– [6]. Showing and vector control of DFIG-based breeze turbine under uneven conditions in little scale structures are comprehensively tended to in composing [7]– [11]. The current uneven vector control anticipates DGs routinely use two arrangements of individual controllers for the positive and negative progression portions of unbalanced streams [12]– [15]. Tuning of these controllers because of the deferrals of the separating positive/negative progressions channels every now and again requires complex figurings in unequal vector control designs [14], [15].Alternative methods have been exhibited which clearly process the uneven rotor current without breaking down into positive/negative sequences[7], [8] and [16], [17]. Regardless, in these systems, the estimation of current references subject to the power throbs moreover requires the positive and negative gathering parts of the machine stator voltage, current, and change. Facilitate control (DPC) systems have been furthermore proposed for unequal voltage condition which tolerably lessen the multifaceted idea of the control technique diverged from the vector control contrive [11], [18]– 20]. Regardless, the DPC systems like the unequal vector control procedures still need breaking down of positive/negative game plans and compensation for the channels delays. This paper demonstrates a control procedure for a DFIG related with a disproportionate system voltage, which uses theprovokeactive/reactive powers as the state factors. The proposed control approach offers a solid structure since its state factors are free of the positive/negative groupings of the DFIG current parts. The prescribed control plan also reduces the DFIG torque/control throbs by using the active/reactive power bearings of the rotor-side converters in a DFIG wind essentialness system. Besides, at low breeze speed and high unequal system voltage conditions, the plenitude furthest reaches of grid side converter can be used for fragmentary pay of uneven stator voltage. Two current/control limiting computations are similarly exhibited for both rotor-and system side converters to avoid over rating of the converters. The execution of the proposed system under disproportionate network voltage condition is inquired about by methods for time-space reenactment of a MW-scale DFIG wind turbine-generator examine structure in which a single stage stack is used to compel a persistent voltage unbalance to the small scale framework.

II. CONVENTIONAL VECTOR CONTROL SCHEME FOR DFIG SYSTEM

Fig1 exhibits the schematic layout of a DFIG WTG including rotor-side (RSC) and network side (GSC) converters. Under organized subject to common vector control or other arrangement techniques, for instance, resonation controller and direct power control using fleeting force model of the DFIG [17], [21]. In any case, under unequal voltage condition, right hand control circles using negative game plans sums must be added to the standard vector speed controllers which outline a comprehensive disproportionate vector control contrive [7], [17].Figure 2 demonstrates nuances of the uneven vector control plot for the rotor-side converter [12], [13]. This control procedure mitigates the torque throbs and the framework unequal effects on the generator by methods for independent control of the stator real/responsive power parts, $p*s$ and $q*s$. The progressive crumbling unit in Fig. 2 registers the positive/negative game plan parts in positive/negative progression qd reference outline.

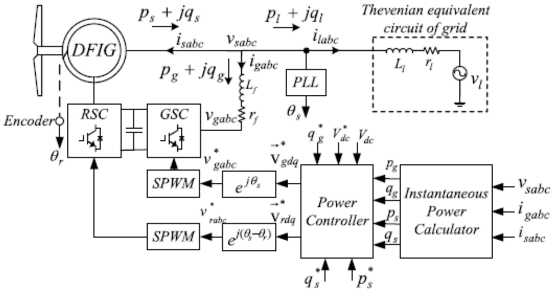


Fig 1. Schematic diagram of DFIG-based Wind Generation System.

Fig. 2, the uneven vector control technique is built up dependent on decompensation of the positive and negative successions of the rotor current. For all intents and purposes, this decay can be acknowledged by exchanging the current to the synchronous reference edge and utilizing computerized channels, or flag defer cancelation strategy. These strategies present time delays and evident blunders in adequacy and stage which antagonistically influence on the dynamic execution of the control framework [20].

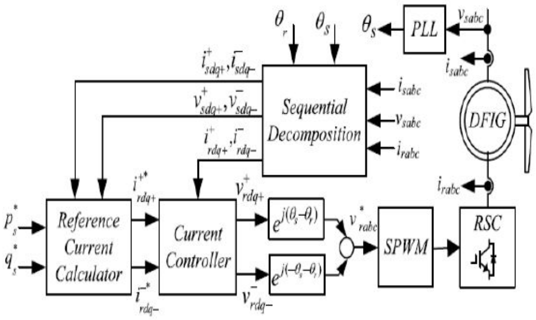


Fig 2. Schematic diagram of the conventional unbalanced vector control scheme for DFIG.

III. PROPOSED CONTROLLER FOR UNBALANCED VOLTAGE CONDITIONS

A. Instantaneous Power Model of a DFIG

The model of the induction machine in terms of the stator real/reactive power components, psand qs is

$$\frac{d}{dt}\begin{bmatrix} p_s \\ q_s \\ \psi_{sd} \\ \psi_{sq} \\ \omega_r \end{bmatrix} = \begin{bmatrix} g_1 & -\omega_{sl} & -g_4 & -g_5 & 0 \\ \omega_{sl} & g_1 & -g_5 & g_4 & 0 \\ \frac{2r_s v_{sd}}{3|v_s|^2} & \frac{2r_s v_{sq}}{3|v_s|^2} & 0 & \omega_e & 0 \\ \frac{2r_s v_{sq}}{3|v_s|^2} & -\frac{2r_s v_{sd}}{3|v_s|^2} & -\omega_e & 0 & 0 \\ g_6 & g_7 & 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} p_s \\ q_s \\ \psi_{sd} \\ \psi_{sq} \\ \omega_r \end{bmatrix} + \begin{bmatrix} u_{rd} \\ u_{rq} \\ v_{sd} \\ v_{sq} \\ \frac{PT_m}{-J} \end{bmatrix} \quad \text{……….1}$$

where subtleties of urd,rq and g1 to g7 are given in Appendix. The lattice side converter and channel demonstrate as far as prompt genuine and responsive intensity of network side converter, pg and qg, is

$$\begin{bmatrix} \frac{dp_g}{dt} \\ \frac{dq_g}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{r_f}{L_f} & -\omega_e \\ \omega_e & -\frac{r_f}{L_f} \end{bmatrix}\begin{bmatrix} p_g \\ q_g \end{bmatrix} + \frac{1}{L_f}\begin{bmatrix} u_{gd} \\ u_{gq} \end{bmatrix} \quad \text{……2}$$

Where

$$u_{gd} = \frac{3}{2}\left(\left|v_s{}^2\right| - \left(v_{gd}v_{sd} + v_{gq}v_{sq}\right)\right) \quad \text{……..3}$$

And

$$u_{gd} = \frac{3}{2}\left(v_{gq}v_{sd} - v_{gd}v_{sq}\right) \quad \text{….4}$$

The dynamic model of the dc link is:

$$\frac{dv_{dc}}{dt} = \frac{i_{dc}}{C} - \frac{P_G - P_r}{CV_{dc}} \quad \text{……5}$$

where the real power delivered to the rotor, pr, is:

$$p_r = \frac{3}{2}\left(v_{rd}i_{rd} + v_{rq}i_{rq}\right) \quad \text{….6}$$

Equations (1)-(6) summarize the model of a DFIG wind power system including the machine and converters.

B. Compensation of Unbalanced Voltage Utilizing GSC

The excess furthest reaches of system side converter at low breeze speed can be used for a midway compensation of uneven stator voltage. This can be practiced through the control of the authentic/open power in GSC contrasting with the negative gathering of the cross section voltage. This zone develops the logical association between the power throb and the negative course of action voltage which is required in the structure technique for the control system. The current/voltage vectors can be imparted the extent that their game plan parts in +/ - synchronous reference traces as:

$$f_{dq}^{+} = f_{dq}^{+} + f_{dq}^{+} = f_{dq}^{+} + f_{dq}^{-} - e^{-j\omega e^{t}}$$

……7

Based on(7), the instantaneous real/reactive power components can be obtained via definition of complex power as:

$$s_g(t) = p_g(t) + jq_g(t) = \frac{3}{2} v_{sdq}^{+} i_{gdq}^{+}$$

$$\frac{3}{2}\left(v_{sdq}^{+} + i_{gdq}^{+} - e^{-i2\omega e^{t}}\right)\left(i_{gdq}^{+} + i_{gdq}^{-} - e^{j2\omega e^{t}}\right)$$

$$= \frac{3}{2}\left(v_{sdq+}^{+} i_{gdq}^{+} + v_{sdq}^{-} i_{gdq-}^{-}\right)$$

$$+ \frac{3}{2}\left(v_{sdq}^{+} + i_{gdq}^{-} - e^{j2\omega e^{t}} + v_{sdq}^{-} - i_{gdq}^{+} + e^{-J2\omega} e^{t}\right.$$

…8

Fig3 demonstrates the schematic graph of the framework side converter model and DFIG regarding power segments dependent on (1) and (16)- (22). In this model, control throb references for GSC are utilized for modifying the negative grouping lattice voltage.

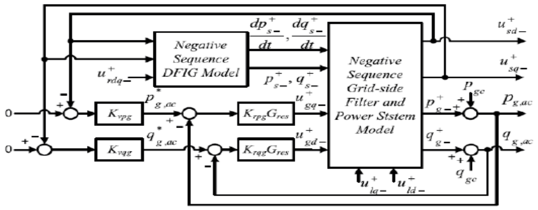


Fig3. Schematic diagram of the GSC model for compensating the negative sequence of the grid voltage

Figure 4 portrays the proposed control framework for matrix side converter. In this control framework, GPg, Gqg and Gdc controllers are structured dependent on adjusted model as explained in [21]. At that point, additional control circles including Kvdg, Kvqg, KrpgGres and KrqgGres are utilized to control throbs of converter relating to throbs of lattice voltage at positive succession reference outline. The full compensator (Gres) tuned at the twofold recurrence of the matrix which is actualized in the positive succession reference outline. The step channel Gnf is additionally utilized for stifling the dc-interface voltage twofold recurrence (2ωe) swell. The exchange elements of resounding compensator and step channel (Gnf) which are tuned at ω0 = 2ωe recurrence are:

$$G_{res} = \frac{\frac{\omega_0}{Q} s}{S^2 + \frac{\omega_0}{Q} s + \omega_0^2}, \quad G_{res} = \frac{S^2 + \omega_0^2}{S^2 + \frac{\omega_0}{Q} s + \omega_0^2}$$

….9

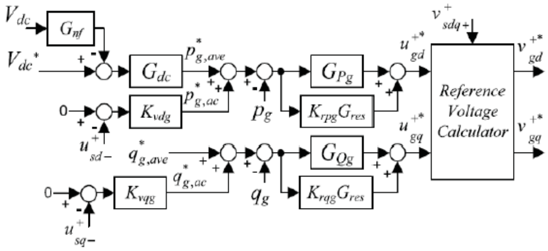


Fig 4. Details of the proposed unbalanced controllers for the grid-side converter.

C. Mitigation of Torque/Reactive Power Pulsations Using RSC

In spite of the fact that GSC to some degree can remunerate the uneven matrix voltage, the torque and power throbs still exist because of 2ωe swell which superimposed on the dc-connect voltage. The torque throb in a generator expands weight on the pivoting shaft of the DFIG which can cause shaft weariness or other mechanical harms to a WTG. Subsequently, a control arrangement is required for the rotor-side converter to alleviate the torque/control throbs of DFIG. Santos-Martin et al. in [23] demonstrate that the concurrent end of the torque and genuine power throbs can't be performed under uneven framework voltage condition. In this way, the proposed control plot thus is intended to remunerate the torque and receptive power throbs as appeared in Fig. 5.Krps, Krqsand Kr Teare steady gains and Gresis a band pass channel tuned at twofold recurrence as given in (23). The electric torque can be evaluated by stator and rotor flow parts in the stationary reference outline as

$$T_e = \frac{3pL_m}{2}\left(i_{sQ} i_{rD} - i_{sD} i_{rQ}\right) \quad ....10$$

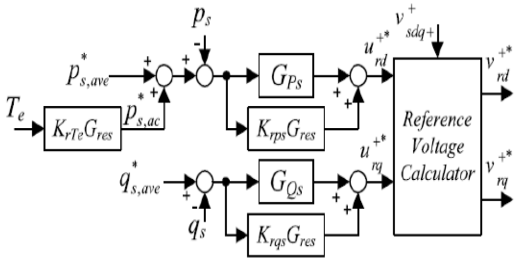


Fig 5. Details of the proposed unbalanced controllers for the rotor-side converter.

IV. DESIGN OF TYPE-2 FUZZY LOGIC CONTROLLER

At the point when a framework has impressively vast sureness, Type 1 Fuzzy Logic Controller (T1FLC) can't achieve the ideal dimension of execution with a reasonable multifaceted nature of the structure. In such cases, the utilization of Type 2 Fuzzy Logic Controller (T2FLC) is prompted as the good FLC in the examinations in territories, for example, determining of time-arrangement, controlling of portable robots, the truck backing-up control issue, Very Large Scale Integration (VLSI) and Field Programmable Logic Devices (FPGA) .Executions of T2FLC uncovers that when the parameters are suitably balanced, T2FLC can result in a superior capacity to foresee when contrasted with T1FLC [Liang Q and Mendel J. M (2000)]. For machines like continuous portable robots, T2FLCs are most appropriate application. For the instance of continuous usage, writing overview demonstrates that a customary T1FLCs can't deal with the vulnerabilities in the framework effectively and a T2FLC utilizing type-2 fuzzy sets results in a superior execution. Likewise, by utilizing T2FLC the amount of controls to be resolved additionally diminishes in spite of the fact that the parameters to be resolved don't get decreased.

Hagras, H. (2007) displayed that Type-2 fuzzy sets are finding wide appropriateness in guideline based fuzzy rationale frameworks (FLSs) in light of the fact that they let vulnerabilities be demonstrated by them though such vulnerabilities can't be displayed by Type-1 fuzzy sets. A square graph of a Type-2 Fuzzy Logic System (T2FLS) is portrayed in Figure 5.1.

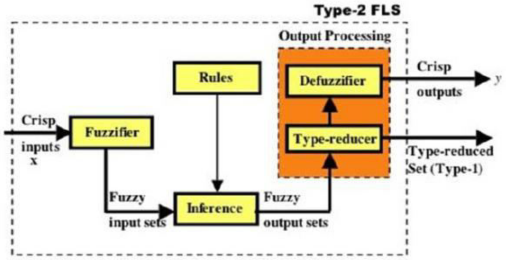


Figure 6: Block diagram of Type-2 Fuzzy Logic System

In the square chart, there is an additional square - type reducer, which is absent in Type-1 FLS yet is required in Type-2 FLS structure. In spite of the fact that the Type 2 FLS has a few points of interest when managing vulnerabilities, however it likewise expands the numerical computation.

The squares of Type 2 FLS are as:

a) Fuzzifier: The fuzzifier maps fresh contributions to Type-2 fuzzy sets which enacts the deduction motor.

b) Rule base: The principles in a T2FLS and T1FLS are same, yet predecessors and consequents are spoken to by Type-2 fuzzy sets.

c) Inference: Inference square doles out fuzzy contributions to fuzzy outputs utilizing the guidelines in the standard base and the administrators, for example, association and crossing point.

d) Type-decrease: The Type-2 fuzzy outputs of the deduction motor are changed into Type-1 fuzzy sets that are known as the sort diminished sets. There are two normal techniques for the sort decrease activity in the T2FLSs: One is the Karnik-Mendel cycle calculation, and the other is Wu-Mendel vulnerability limits strategy.

e) Defuzzification: The second step of yield handling, which happens after sort decrease, is still called defuzzification. Since a sort decreased arrangement of an Interval type-2 fuzzy set is dependably a limited Interval of numbers, the defuzzified esteem is only the normal of the two end-purposes of this Interval.

V.SIMULATION RESULTS

MATLAB/SIMULINK results are introduced in this area for approving unfaltering state and dynamic exhibitions of this proposed DFIG with incorporated dynamic channel capacities.

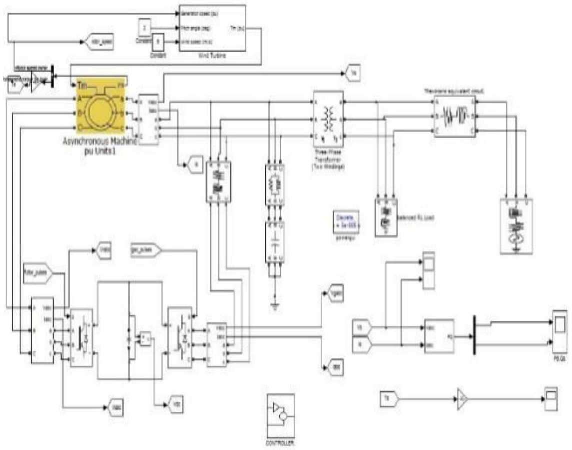


Fig 7.MATLAB.SIMULINK diagram of proposed type-2 fuzzy controller based DFIG

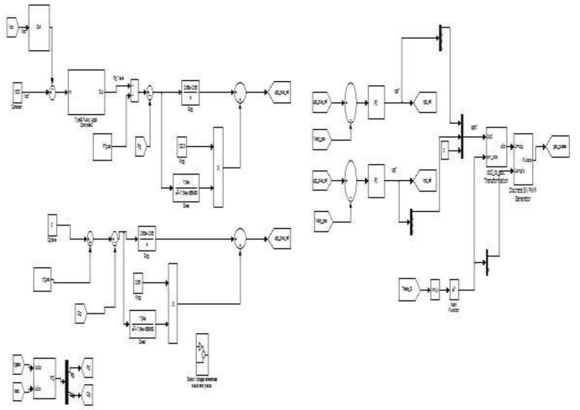


Fig 8.Grid side Controller with Type-2 Fuzzy controller

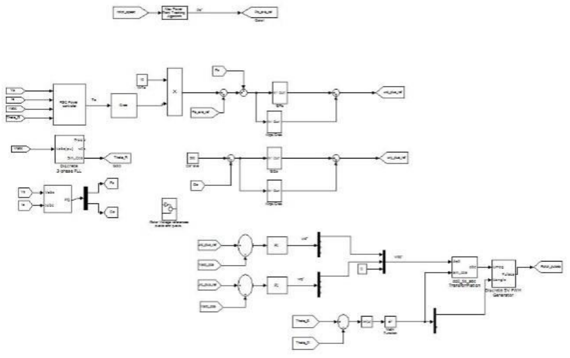
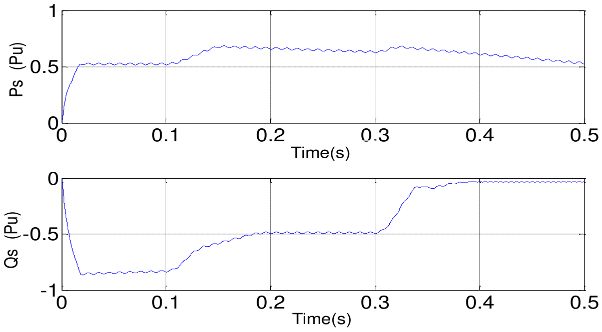
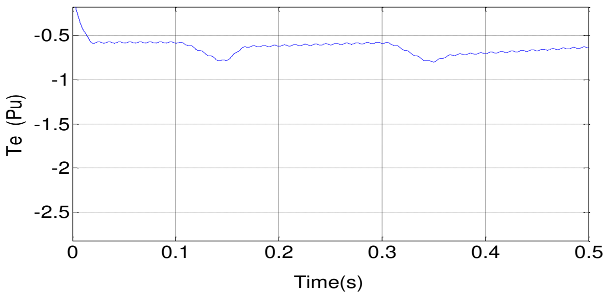


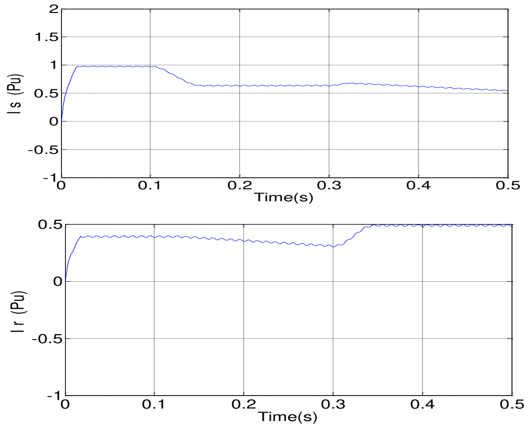
Fig 9.Rotor side Controller with Type-2 Fuzzy controller



(a) stator real power; (b) stator reactive power;

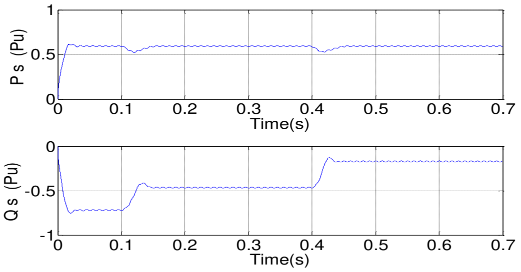


(c) Torque;

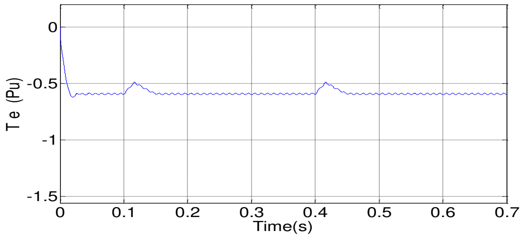


(d) stator and rotor currents.

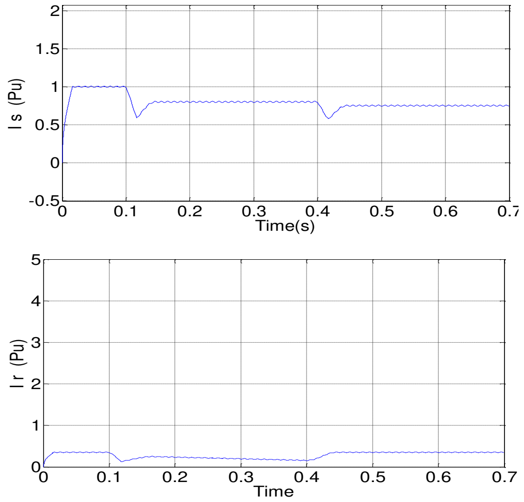
Fig 10.The DFIG performance under unbalanced voltage using balanced controller



(a) stator real power; (b) stator reactive power;

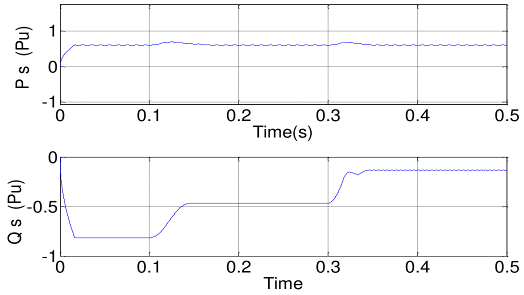


(c) torque;

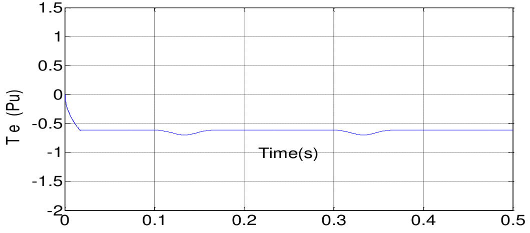


(d) Stator and rotor currents.

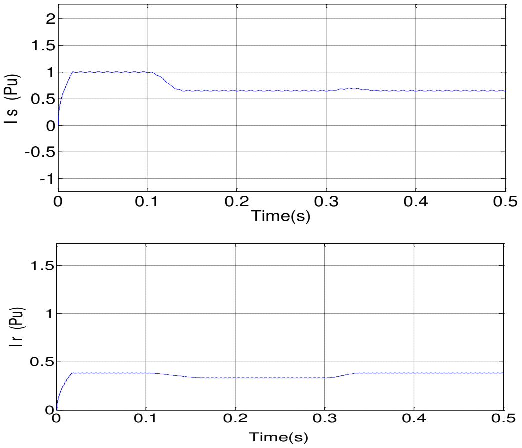
Fig. 11. Unbalanced vector controller:



(a) Stator real power; (b) stator reactive power;

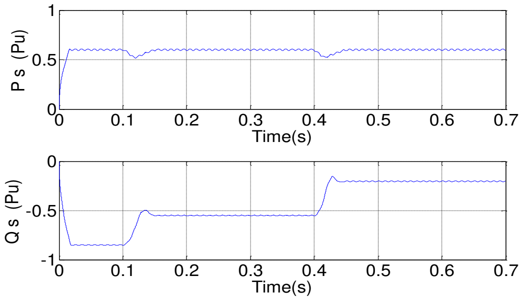


(c) Torque;

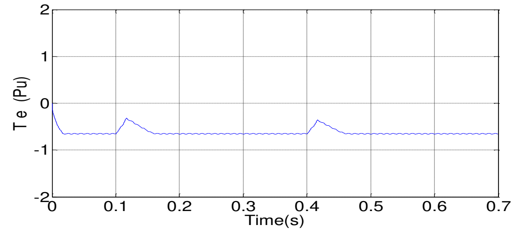


(d) Stator and rotor currents.

Fig.12. the proposed controller

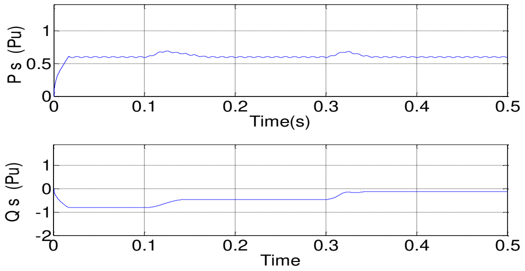


(a) Stator real power;(b) stator reactive power;

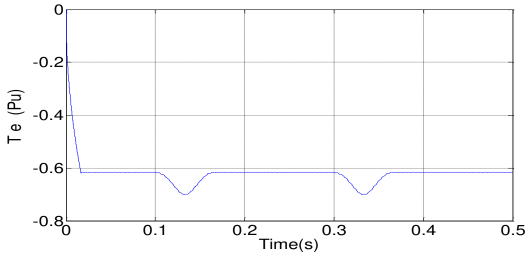


(c) Torque.

Fig.13. Robustness of the unbalanced vector controller:

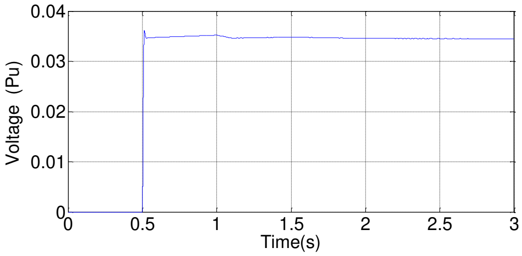


(a) Stator real power; (b) stator reactive power;

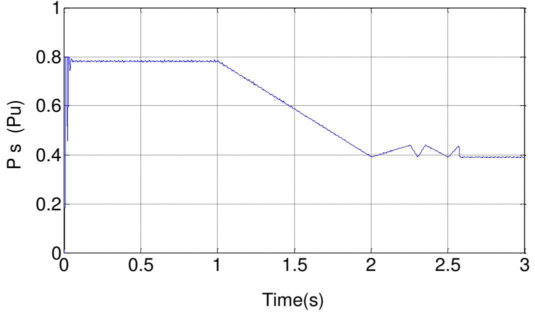


(c) Torque.

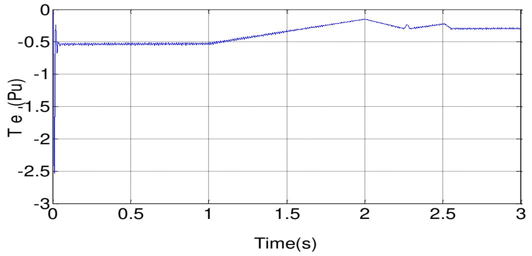
Fig.14. Robustness of the proposed controller:



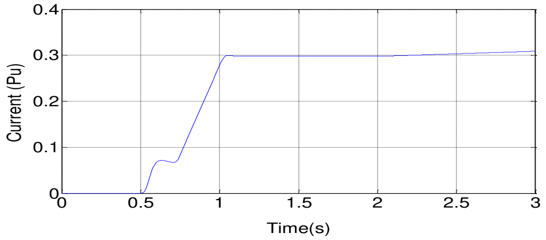
(a) Negative sequence of the stator voltage;



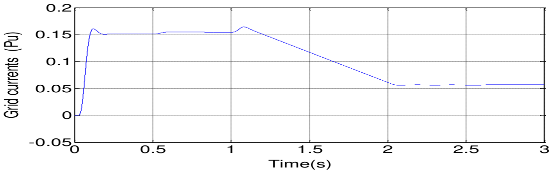
(b) Stator real power;



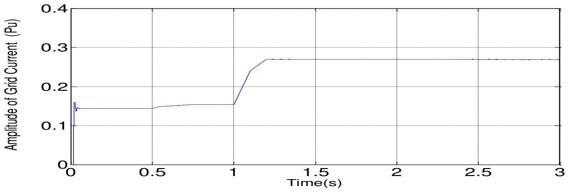
(c) Torque;



(d) Negative sequence grid-side converter current.



(e) Positive sequence grid-side converter current;



(f) Amplitude of the grid-side converter current.

Fig.15. Partial compensation of unbalanced stator voltage

CONCLUSION

A DFIG wind turbine-generator with Type-2 Fuzzy controller has been introduced in this paper which does not require the successive decay of the DFIG stator/rotor flows and is less sensitive to the framework parameters. This control method mitigates the stator reactive power and torque ripples which obviously appear in any balanced control scheme under an unbalanced grid voltage condition. The control strategy utilizes the grid side converter to in part remunerate the unbalance stator voltage when the wind speed is low and turbine works below nominal power. It has been demonstrated that proposed control approach dependent on its basic and robust structure can offer a promising solution for DFIG control under unbalanced grid voltage conditions. In the extension proposed Type-2 fuzzy controller.The traditional type-1 FLCs that use crisp type-1 fuzzy sets cannot directly handle such uncertainties. Type-2 FLCs that utilize type-2 fuzzy sets can handle such uncertainties to produce a better performance. Hence, type-2 FLCs will have potential to overcome the limitations of type-1 FLCs and produce a new generation of fuzzy controllers with enhanced performance for many applications which require handling high levels of uncertainty.

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