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Singular Pitch Control For Mitigation Of Power Fluctuation

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ABSTRACT: Matrix associated wind turbines are the wellsprings of energy vacillations amid persistent operation because of wind speed variety, wind shear and tower shadow impacts. This paper exhibits an individual pitch control (IPC) system to moderate the breeze turbine control variance at both above and beneath the evaluated wind speed conditions. Three pitch points are balanced independently as indicated by the generator yield control and the azimuth edge of the breeze turbine. The IPC system plot is proposed and the individual pitch controller is planned. The recreations are performed on the NREL (National Renewable Energy Laboratory) 1.5MW upwind reference wind turbine show. The reproduction comes about are introduced and examined to demonstrate the legitimacy of the proposed control strategy.

KEYWORDS: wind turbine; IPC; power fluctuation; FAST

I. INTRODUCTION

Amid the most recent couple of decades, with the developing concernsabout natural contamination and vitality deficiency, greatefforts have been taken far and wide to implementrenewable vitality ventures. With cutting edge strategies, costreduction and low natural effect, wind vitality iscertain to assume an essential part on the planet's vitality [1]. Withthe limit increment of the breeze turbines, twist powerpenetration into the network increments drastically and the powerquality turns into a vital issue.Grid associated variable speed wind turbines are fluctuatingpower sources amid nonstop operation. The powerfluctuation is regularly alluded to as the 3p motions whichare caused by wind speed variety, wind shear and towershadow impacts. As a result, the breeze turbineaerodynamic power will drop three times for every insurgency for athree-bladed breeze turbine.Several techniques have been proposed for the moderation ofwind control changes of matrix associated wind turbines insome writings. Receptive power remuneration is the mostcommonly utilized system, be that as it may, this strategy demonstrates itslimits, when the lattice impedance point is low in somedistribution systems [2]. Additionally dynamic power control by varyingthe DC-connect voltage of the consecutive converter is presentedto weaken the power vacillation [3]. Be that as it may, a major DC-linkcapacitor is required in the technique because of the capacity of thefluctuation control in the DC-connect. These papers usecompensation or assimilation techniques to decrease the poweroscillations, which have not tackled the issue from thesource part of wind turbine framework for the power variances.
Various arrangements have been displayed to relieve theflicker discharge of framework associated wind turbines. The mostcommonly received method is the receptive power remuneration [6]. Nonetheless, the flash relief strategy indicates itslimits in some conveyance systems where the network impedanceangle is low [7]. At the point when the breeze speed is high and the gridimpedance edge is 10◦, the responsive power required for flickermitigation is 3.26 for every unit [8]. It is troublesome for a network sideconverter (GSC) to produce this measure of receptive power, particularly for the doubly nourished enlistment generator (DFIG) system,of which the converter limit is just around 0.3 for each unit. TheSTATCOM which gets much consideration is additionally embraced toreduce glint outflow.
In any case, it is probably not going to be financiallyviable for appropriated age applications. Dynamic power control by differing the dc-connect voltage of the consecutive converteris displayed to lessen the flash emanation [8]. Be that as it may, a bigdc-connect capacitor is required, and the lifetime of the capacitorwill be abbreviated to store of the variance control in the dc link.An open-circle contribute control is utilized [6] and [8] to investigatethe gleam outflow in high breeze speeds, be that as it may, the pitchactuation framework (PAS) isn't considered. Since thepitch rate and the time deferral of the PAS make incredible contributionsto the aftereffects of the flash discharge of variable-speed windturbines, it is important to contemplate these elements.

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II. POWER FLUCTUATION ANALYSIS

Power generated by wind turbines is much more variablethan that produced by conventional generators. The powerfluctuations are due both to stochastic processes that determinewind speed at different times, and to periodic processes that arereferred to as wind shear and tower shadow.

Wind shear is usedto describe the variation of wind speed with height while towershadow describes the redirection of wind due to the towerstructure [4].

A. Wind shear

The increase of wind speed with height is known as windshear. A common wind shear model, shown as (1), is takendirectly from the literature on wind turbine dynamics [4]

B. Tower shadow

Today most wind turbines are constructed with a rotorupwind of the tower to reduce the tower interference of thewind flow. In the upwind rotor case, the wind speed Vtowconsidering tower shadow effect can be modeled usingpotential flow theory [4].

C. Total aerodynamic torque

Fig. 1 illustrates theoverall wind turbine aerodynamic torque, which obviouslyshows the 3p effect, and also the aerodynamic torque has themaximum drop when one of the three blades is directly in frontof the tower.

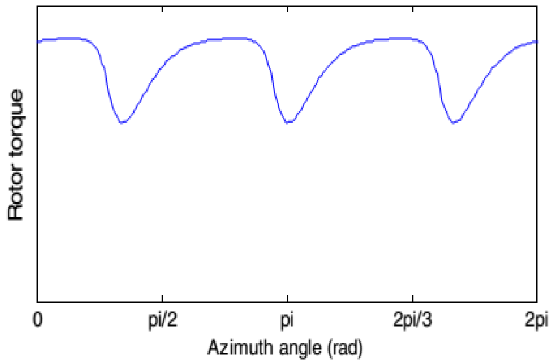

Figure 1. Aerodynamic torque involving 3p effects

III. SYSTEM CONFIGURATION

The overall scheme of DFIG based wind turbine system isshown in Fig 2, which consists of a wind turbine, gearbox,DFIG, a back-to-back converter which is composed of rotorside converter (RSC) and grid side converter (GSC) and a dclink capacitor as energy storage placed between the twoconverters. In this paper, turbulent wind is simulated byTurbSim. Wind turbine code FAST is used to simulate themechanical parts of wind turbine and the drivetrain. The pitchand converter controllers, DFIG, and power system aremodeled by Simulink blocks.

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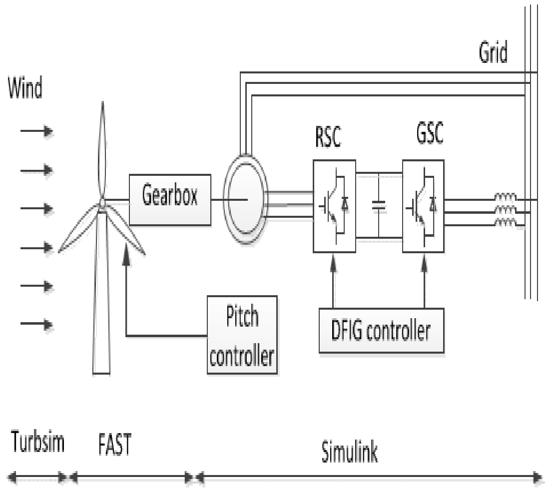

Fig. 2. The overall scheme of the DFIG based wind turbine system

A. TurbSim and FAST

TurbSim and FAST are developed at the NationalRenewable Energy Laboratory (NREL) and they are accessibleand free to the public. TurbSim is a stochastic, full-field,turbulent-wind simulator. It numerically simulates time seriesof three-dimensional wind velocity vectors at points in avertical rectangular grid. TurbSim output can then be used asinput into FAST [5]. The open source code FAST can be usedto model both two and three bladed, horizontal-axis windturbines. It uses Blade Element Momentum (BEM) theory tocalculate blade aerodynamic forces and uses an assumedapproach to formulate the motion equations of the windturbine. For three-bladed wind turbines, 24 DOFs (Degree of Freedoms) are used to describe the turbine dynamics. Theirmodels include rigid parts and flexible parts. The rigid partsinclude earth, base plate, nacelle, generator, and hub. Theflexible parts include blades, shaft, and tower. FAST runssignificantly faster than a large comprehensive code such asADAMS because of the use of the modal approach with fewerdegrees of freedoms (DOFs) to describe the most important
parts of turbine dynamics.

B. Mechanical Drivetrain

In order to take into account the effects of the generator anddrivetrain to the wind turbine, two-mass model is used which issuitable for transient stability analysis [6] shown in Fig. 3. Thedrivetrain modeling is implemented in FAST, and all values are cast on the wind turbine side.

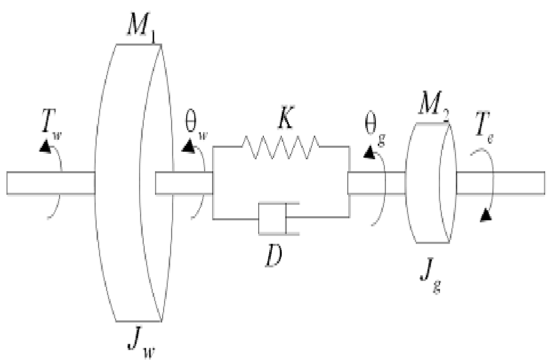

Figure 3. Two-mass model of the drivetrain

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C. DFIG model and converters control

The model of the DFIG in Simulink is based on d-q equivalent model. All electrical variables are referred to thestator.Vector control techniques are the most commonly usedmethods for back to back converters in wind turbine system.

Two vector control schemes are illustrated respectively for theRSC and GSC, as shown in Fig. 4. Normally the controlobjective of RSC is to implement maximum power tracking bycontrolling the electrical torque of DFIG, while the objective of GSC is to keep the DC-link voltage constant.

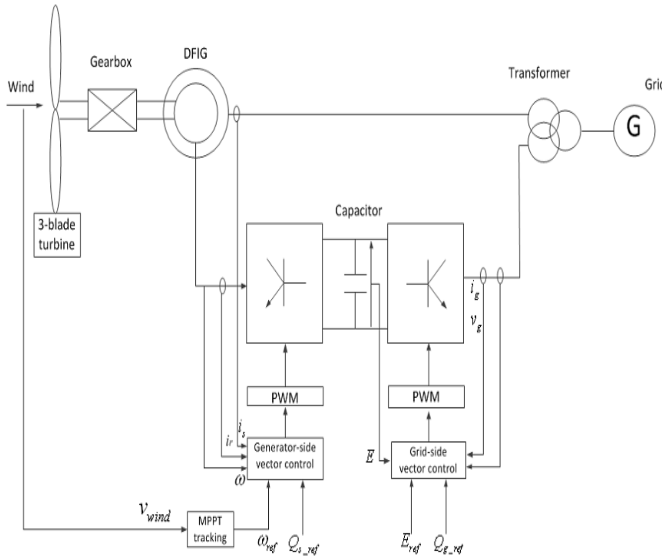

Figure 4. Control diagram of RSC and GSC of grid-connected wind turbine with DFIG

IV. INDIVIDUAL PITCH CONTROL FOR MITIGATION OF WIND TURBINE POWER FLUCTUATION

As illustrated in Fig. 1, the aerodynamic torque will dropthree times per revolution, so that the aerodynamic power ofthe wind turbine as well as the generator output power will alsodrop three times in a cycle. If the aerodynamic torque can becontrolled well to some extent that it will not drop or not drop
so prominently when one of the blades is directly in front of thetower, the wind turbine aerodynamic power thus the generatoroutput power will fluctuate in a much smaller range.When wind speed is above rated wind speed, pitch angleshould be tuned by traditional collective pitch control (CPC) tokeep the output power at its rated value in order not to overloadthe system, and normally the 3p effect is not taken intoaccount. For attenuating the power oscillation caused by 3peffect, one of the blade pitch angles can be added by a smallpitch increment which is dependent on the wind turbineazimuth angle and the generator output power.
When wind speed is below the rated wind speed, usuallythe control objective of wind turbine is to implement maximumpower tracking by generator electrical torque control. Pitchcontrol is not used in this area. However if the pitch angles canbe adjusted around a small average value, the 3p effect can also
be reduced. For this purpose, the pitch angle should leave asmall amount of residual for pitch movement. This means partof the wind energy will be lost.Based on this control concept, a novel individual pitchcontrol strategy is proposed. The control scheme is shown inFig. 5.

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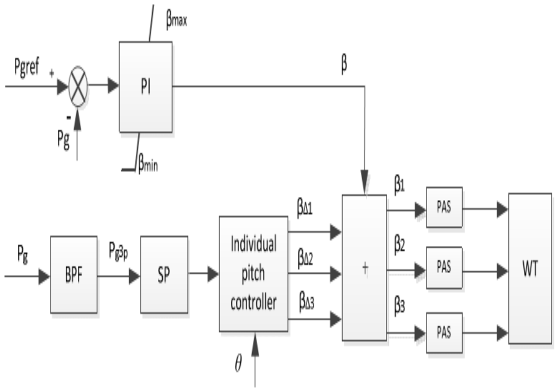

Figure 5. A novel individual pitch control scheme

The control scheme consists of two control loops:collective pitch control loop and individual pitch control loop.The collective pitch control is responsible for limiting theoutput power. In this loop, Pgref is the rated generator power, Pgis the generator output power, β is the collective pitch angle, ofwhich the minimum value βmin can be obtained by simulationsunder different wind speeds such that power fluctuationmitigation may compromise the power loss.In the individual pitch control loop, the BPF (band passfilter) is to let the frequency of 3p generator active powerthrough and block all other frequencies. Pg3p is the 3pcomponent of the generator power, and this component will be sent to the signal processing (SP) block, due to the fact that thepower signal has to be transferred to the pitch signal.

In this paper, the wind turbine is simulated by FAST, inwhich blade 3 is ahead of blade 2, which is ahead of blade 1, sothat the order of blades passing through a given azimuth is 3-2-1-repeat. The individual pitch controller will output a pitchincrement signal which will be added to the collective pitchangle for a specific blade, dependent on the blade azimuthangle. The principle of the individual pitch controller isdescribed in Table 1.

Table I. Control principle of individual pitch controller

Azimuth angle θ	$\beta_{\Delta i}$
$0< \theta <2\pi/3$	$\beta_{\Delta 2}$
$4\pi/3> \theta >2\pi/3$	$\beta_{\Delta 1}$
$2\pi> \theta >4\pi/3$	$\beta_{\Delta 3}$

V. SIMULATION RESULTS

In order to verify the validity of the proposed individualpitch control strategy, the whole wind turbine system is built inSimulink, and some simulation results are obtained under bothhigh and low wind speeds.

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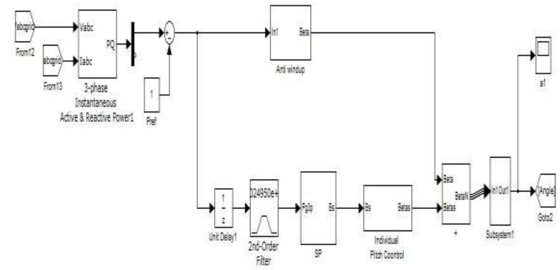

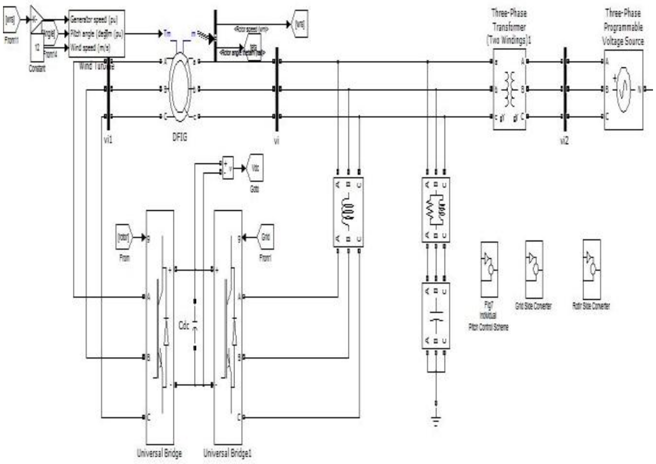

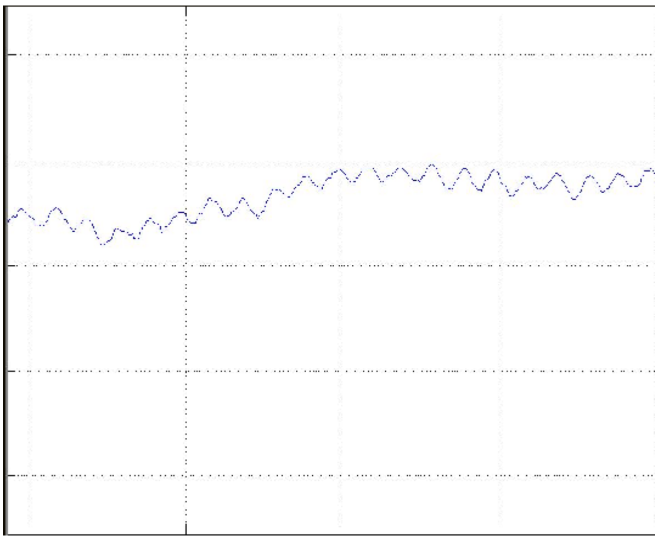

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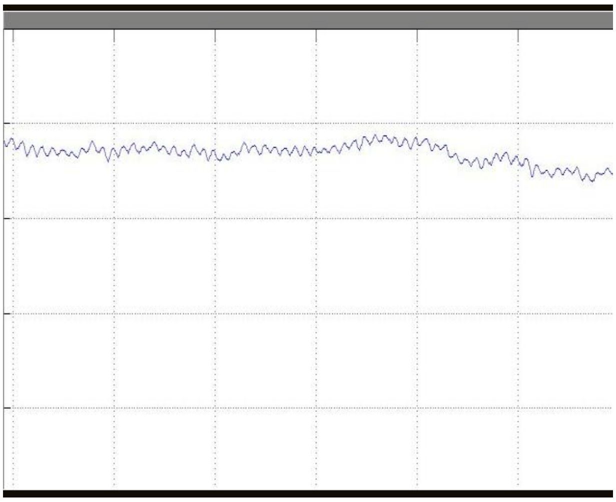

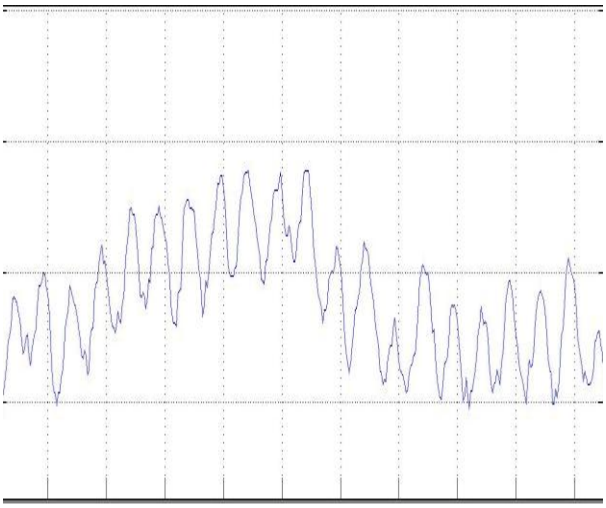

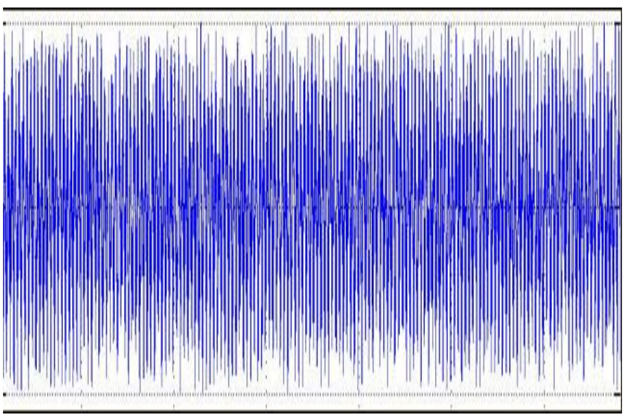

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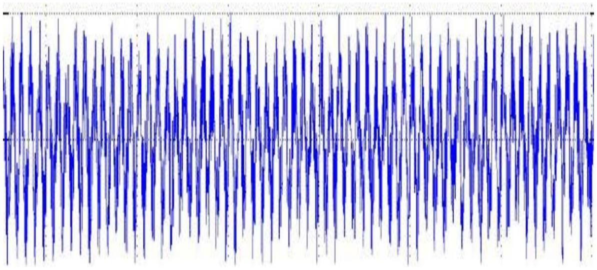

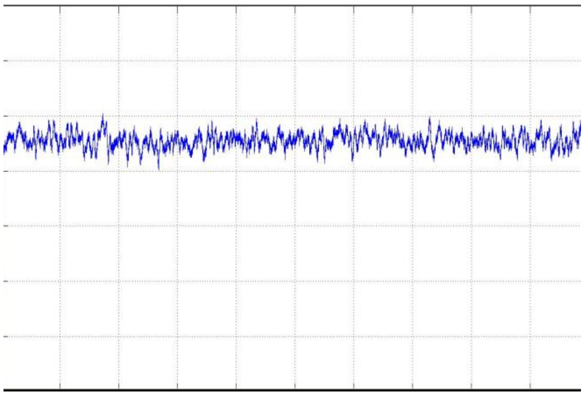

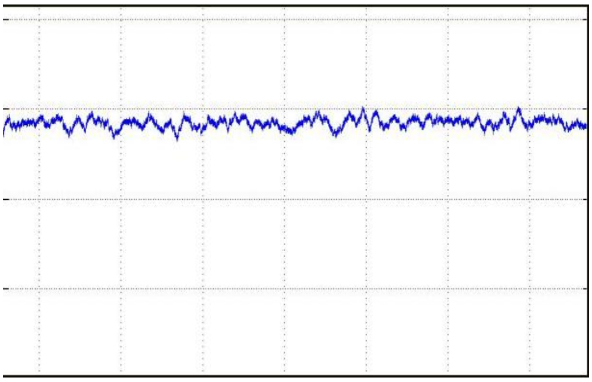

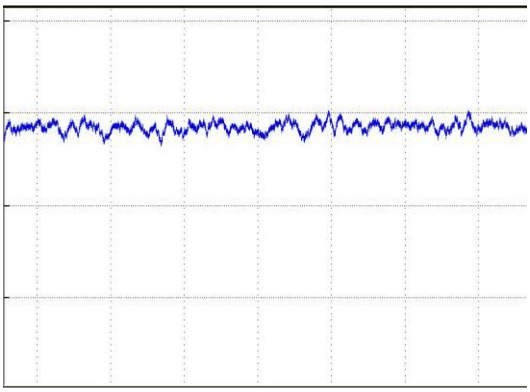

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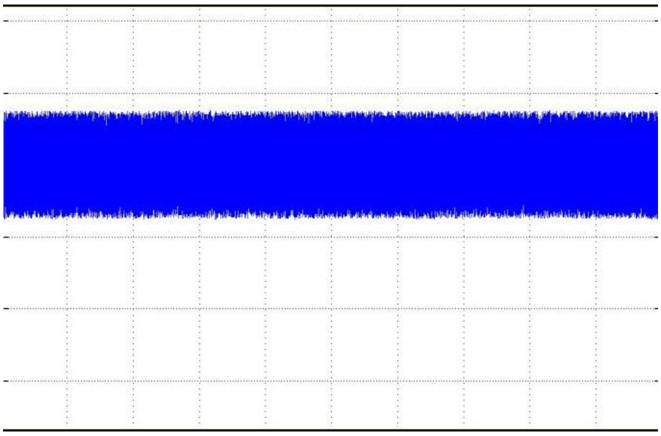

VI. CONCLUSION

The MW-level DFIG based variable speed wind turbinesystem is reenacted utilizing Simulink, Turbsim and FAST. Anovel singular pitch control technique is proposed to mitigatethe wind turbine control vacillation caused by wind shear andtower shadow impacts. The individual pitch control conspire ispresented and controller is planned. The reproductions areperformed on the NREL 1.5MW upwind reference windturbine show. The recreation comes about show thecapability of the proposed system.

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