Individual Pitch Controller for the Speed Controlling of Wind Turbines with Fuzzy Logic under Voltage Dips

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Abstract

The wind turbine never maintained the speed as constant, because of shadow effects and wind shear mechanism produced irregularities of speed when the wind turbines are connected to the grid. Also the generation of power contains oscillations because of sags are involved with in the continuous mode of operations. This paper concentrated on the utilization of MW- level wind turbine variable speed from the double fed induction generator identified the presence of sags and their compensations. In order to maintain the compensation purpose here introduced individual pitch control strategy for control the generation of sags at variable speed drive environment conditions. The controller which is organized according to the active power generation from the grid and azimuth angles from the wind turbine. Fuzzy logic controller is provided to achieve the required to achieve the yielded responses from the wind power systems. The simulation model results are tested and verified under the MATLAB/ SIMULINK for the wind turbine models. When we observe the waveforms explains that they contain less damping oscillation from the wind turbine in continuous mode operation also IPC compensate the sags problem effectively from the wind turbines.

Keywords — *voltage dip, voltage dip mitigation, individual pitch control (IPC), variable speed wind turbine, fuzzy logic controller (FLC)*

I. INTRODUCTION

Among the most recent couple of decades, with the developing worries about vitality lack and ecological contamination, incredible endeavors have been taken the world over to execute renewable vitality ventures, particularly wind force ventures. With the increment of wind force entrance into the network, the force quality turns into an imperative issue. One critical part of force quality is Flicker since it could turn into a constraining variable for coordinating wind turbines into feeble lattices, and even into generally solid frameworks if the wind power infiltration levels are high [1].

Flash is characterized as "an impression of insecurity of visual sensation impelled by a light boost, whose luminance or unearthly dispersion varies with time"[2]. Gleam is incited by voltage variances, which are brought about by burden stream changes in the matrix. Lattice associated variable rate wind turbines are fluctuating force sources among persistent operation.

The force vacillations brought about by wind speed variety, wind shear, tower shadow, yaw mistakes, and so forth. Prompt the voltage changes in the system, which may create gleam [3]. Aside from the wind force source conditions, the force frame work qualities additionally have sway on gleam outflow of lattice associated wind turbines, for example, cut off and matrix impedance point [4],[5].

The glint outflow with diverse sorts of wind turbines is very distinctive. Despite the fact that variable-rate wind turbines have better execution as to the gleam outflow than settled rate wind turbines, with the vast increment of wind force infiltration level, the glint study on variable velocity wind turbines gets to be essential and basic.

Various arrangements have been displayed to alleviate the glint discharge of framework associated wind turbines. The most generally received strategy is the responsive force remuneration [6]. Be that as it may, the flash relief system demonstrates its points of confinement in some conveyance systems where the framework impedance edge is low.

At the point when the wind pace is high and the matrix impedance edge is 10◦, the responsive force required for Flicker moderation is 3.26 for each unit [8]. It is troublesome for a network side converter (GSC) to produce this measure of responsive force, particularly for the doubly encouraged impelling generator (DFIG) framework, of which the converter limit is just around 0.3 for each unit.

The STATCOM which gets much consideration is likewise embraced to diminish glint discharge. In any case, it is unrealistic to be monetarily feasible for appropriated era applications. Dynamic force control by differing the dc-join voltage of the consecutive converter is exhibited to constrict the glint outflow. In any case, a major dc-join capacitor is required, and the lifetime of the capacitor will be abbreviated to store of the variance power in the dc join.

An open-circle contribute control is utilized and to research the gleam discharge in high wind speeds, in any case, the pitch activation System (PAS) is not considered [9]-[11]. Since the pitch rate and the time deferral of the PAS make incredible commitments to the consequences of the Flicker emanation of variable-pace wind turbines, it is important to look into these components.

As of late, IPC which is a promising path for burdens diminishment has been proposed, from which it is eminent that the IPC for auxiliary burden decrease has little effect on the electrical force. However in this paper, an IPC plan is proposed for glint alleviation of network joined wind turbines.

The power oscillations are weakened by individual pitch edge conformity as indicated by the generator dynamic force criticism and the wind turbine azimuth edge in a manner that the voltage vacillations are smoothed noticeably, prompting the flash relief.

The impact of the glint outflow on the basic burden is likewise researched. The FAST (Fatigue, Aerodynamics, Structures, and Turbulence) code [12] which is equipped for recreating three-bladed wind turbines is utilized as a part of the simulation.

II. PROPOSED TECHNOLOGY

A. *Wind Turbine Configuration:*

The general plan of a DFIG-based wind turbine framework is appeared in Fig. 1, which comprises of a wind turbine, gearbox, DFIG, a consecutive converter which is made out of a rotor side converter (RSC) and GSC, and a dc-join capacitor as vitality capacity put between the two converters. In this paper, FAST is utilized to mimic the mechanical parts of wind turbine and the drivetrain. The pitch and converter controllers, DFIG, and power framework are demonstrated by Simulink pieces.

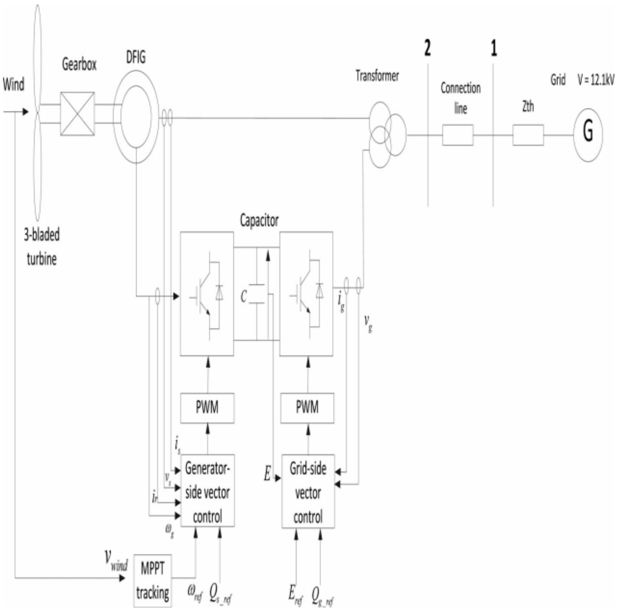


Fig. 1. Overall Scheme Of The DFIG-Based Wind Turbine System.

1) FAST

The open source code FAST is produced at the National Renewable Energy Laboratory (NREL) and available and free to people in general. Quick can be utilized to demonstrate both two and three bladed, flat hub wind turbines. It utilizes Blade Element Energy hypothesis to compute edge streamlined powers and utilizes an expected way to deal with detail the movement mathematical statements of the wind turbine.

For three-bladed wind turbines, 24 degree of opportunities (DOFs) is utilized to depict the turbine flow. Their models incorporate unbending parts and adaptable parts. The inflexible parts incorporate earth, base plate, nacelle, generator, and center point. The adaptable parts incorporate sharp edges, shaft, and tower. Quick runs altogether quick as a result of the utilization of the modular methodology with less DOFs to depict the most essential parts of turbine flow.

2) Mechanical Drive train

In order to take into account the effects of the generator and drive train on the wind turbine, two-mass model shown in Fig. 2

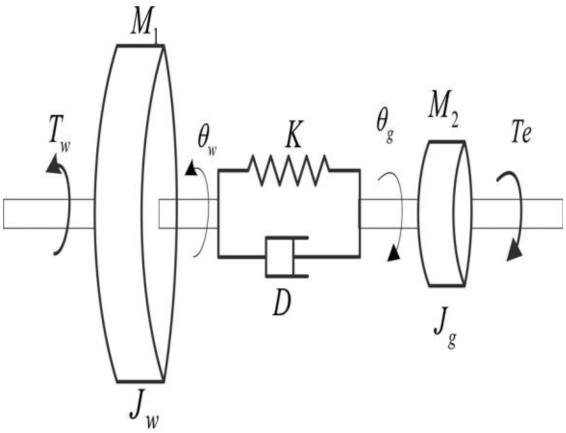


Fig. 2.Two-Mass Model Of The Drive Train.

Which is suitable for transient stability analysis is used. The drive train modeling is implemented in FAST, and all values are referred to the wind turbine side.

The equations for modeling the drive train are given by

$$J_w \frac{d^2\theta_w}{dt^2} = T_\omega - D\left(\frac{d\theta_\omega}{dt} - \frac{d\theta_g}{dt}\right) - K(\theta_\omega - \theta_g)$$
$$J_g \frac{d^2\theta_g}{dt^2} = D\left(\frac{d\theta_\omega}{dt} - \frac{d\theta_g}{dt}\right) + K(\theta_\omega - \theta_g) - T_e$$

Where J_w and J_g are the moment of inertia of wind turbine and generator, respectively, T_w, T_e are the wind turbine torque and generator electromagnetic torque, respectively, θ_w, θ_g are the mechanical angle of wind turbine and generator, K is the drive train torsion spring, D is the drive train torsion damper.

3) DFIG Model

The model of the DFIG is based on d_q equivalent model shown in Fig. 3. All electrical variables are referred to the stator. u_{ds}, u_{qs}, u_{dr}, u_{qr}, i_{ds}, i_{qs}, i_{dr}, i_{qr} and ψ_{ds}, ψ_{qs}, ψ_{dr}, ψ_{qr} are the voltages, currents, and flux linkages of the stator and rotor in d- and q-axes, r_s and r_r are the resistances of the stator and rotor windings, L_s, L_r, L_m are the stator, rotor, And mutual inductances, L_{1s}, $L_{1r}$are the stator and rotor leakage inductances, w_1 is the speed of the reference frame, w_s are the slip angular electrical speed.

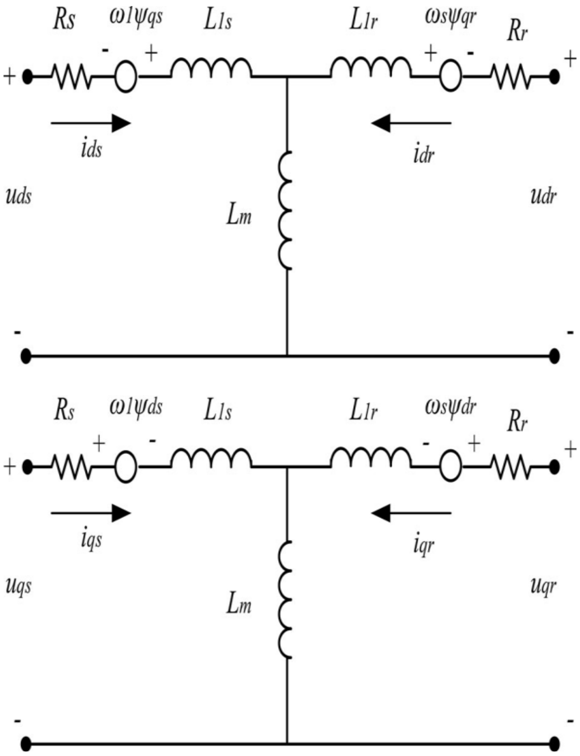


Fig. 3.*D* − *Q* Equivalent Circuit Of DFIG At Synchronously Rotating Reference Frame.

The RSC of DFIG is controlled in a synchronously rotating d-q reference frame with the d-axis aligned along the stator flux position. The electrical torque T_e, active power P_s, and reactive power Q_s of DFIG can be expressed by

$$T_e = \frac{3}{2} p \frac{L_m}{L_s} \varphi_s i_{qr}$$
$$P_s = -\frac{3}{2} u_s \frac{L_m}{L_s} i_{qr}$$
$$Q_s = \frac{3}{2}\frac{\varphi_s}{L_s} u_s - \frac{3}{2} u_s \frac{L_m}{L_s} i_{dr}$$

Where pis the number of pole pairs, $\psi_s$is the stator flux, us is the magnitude of the stator phase voltage .Due to the constant stator voltage, the active power and reactive power can be controlled via i_{qr} and i_{dr}.

B. Wind Turbine Control and Flicker Emission Analysis

For a DFIG-based variable velocity wind turbine, the control goal is diverse as indicated by distinctive wind speed. In low wind speed, the control objective is to keep the tip speed proportion ideal, so that the most extreme force can be caught from the wind. In high twist speed, following the accessible force is past the wind turbine limit, which could over-burden the framework, the control goal is to keep the removed force consistent at its appraised esteem.

1) *Control of Back-to-Back Converter*

Vector control strategies are the most generally utilized techniques for a consecutive converter in a wind turbine framework. Two vector control plans are delineated, individually, for the RSC what's more, GSC.

2) *Pitch Control*

Ordinarily, pitch control is utilized to constrain the streamlined force caught from the wind. In low wind speeds, the wind turbine ought to just attempt to deliver however much power as could reasonably be expected, so there is no compelling reason to pitch the sharp edges.

For wind speeds over the evaluated esteem, the pitch control plan is in charge of restricting the yield power.

3) *Flicker Emission in Normal Operation*

Flicker emission of a framework associated wind turbine framework is actuated by voltage variances which are brought about by burden stream changes in the system, so it is essential to break down the electrical energy to the network.

Along these lines, a recreation is led when the mean wind rate is 13 m/s in view of model.

C. *Individual Pitch Control for Flicker Mitigation*

This area focuses on flicker mitigation of variable speed wind turbines with DFIG among ceaseless operation utilizing IPC. The flash outflow delivered by network associated wind turbines among ceaseless operation is mostly brought on by changes in the generator dynamic force. As represented in Fig. 6, the gleam discharge will be moderated viably if the 3p and higher music of the generator force can be decreased.

Based on this concept, a novel IPC strategy is proposed. The control scheme is shown in Fig. 4. The control scheme consists of two control loops: CPC loop and IPC loop.

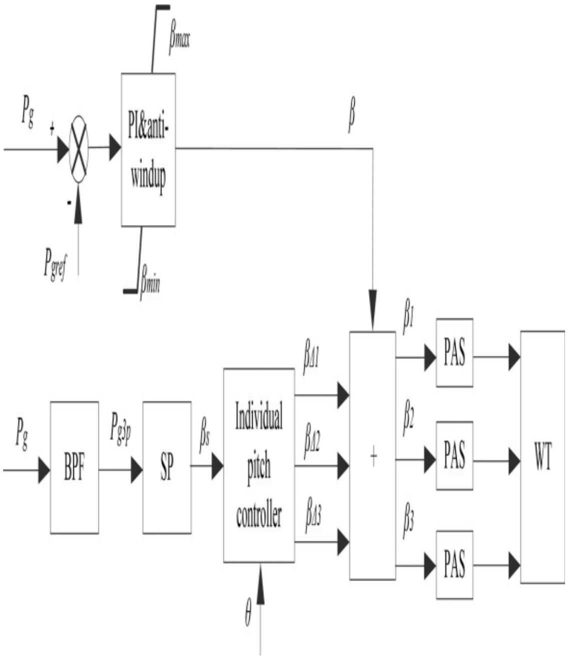


Fig 4.Proposed Individual Pitch Control Scheme.

1) *Design of BPF*

The transfer function of the BPF can be expressed as follows:

$$F(s) = \frac{K_s}{s^2 + \left(\frac{\omega_c}{Q}\right)s + \omega_c^2}$$

Where ωc is the center frequency, K is the gain, and Q is the quality factor.

2) *Signal Processing*

The SP block has to produce a pitch signal to offset the power oscillation, in such a way that the generator power will oscillate in a much smaller range.

III.PROPOSED SIMULINK MODEL

The proposed simulink model is shown in below figure 5. It involves the wind generation system. It consist the parameters of Double fed induction machine generation (DFIG) under ac applications.

The wind generating system is generated power by utilizing the wind turbine. The generated power is transmitted to loads. But the generated power not maintained constant at any instant of time. So at load side the power not maintained to constant it's having always disturbances. The bus selectors are presented to select the required variable from the machine properties.

In this paper we are also presenting three phase fault block which can create the voltage dip problem so the load voltage disturbed and the performance of the system is reduced.

To improve the system performance and behaviour we are provided DFIG Back-to-back converter with the help of Individual pitch controller and grid control by fuzzy logic controller.

The back-back controller consisted two converters to regulate the power and to detect problems. These converters having three-phase voltage source converters individually and one common dc-link capacitor also presented. These are controlled by individual controllers, one converter is interconnected to grid side and another one interconnected to rotor side of DFIG. The voltage source converters either acts as rectifier neither acts as a inverter depends upon the requirement application they will operate in that manner.

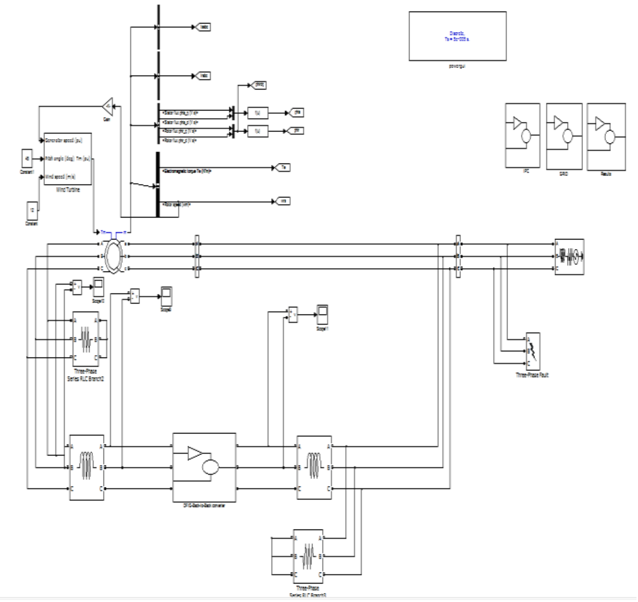


Fig 5: Proposed Simulink Model With Voltage Dip Problem

The individual pitch angle controller is presented to the rotor side three phase converters. The IPC controller is shown in below figure 6.

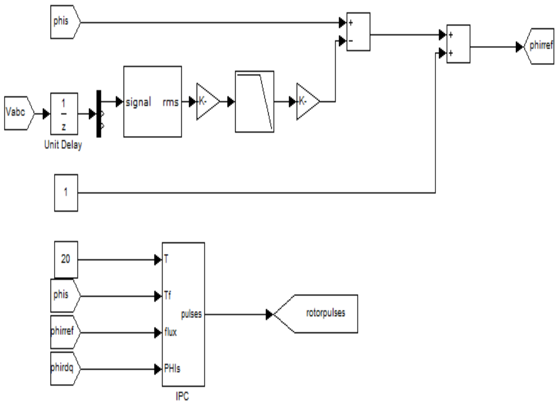


Fig 6: Individual Pitch Controller For Rotor Side Control

The Individual pitch controller is used to bind the aerodynamic power captured from the wind. The stator pitch angle measurement is utilized and can compare with the generated voltage from the wind power plant. The compared signals can generate the reference rotor pitch angle.

The IPC operated with the parameters of rotor side pitch angle and stator side pitch angle rotor side direct and quadarature axis measurements with reference torque levels.

The stator pitch angle control can generate the torque and the rotor sides pitch angle control the flux in the network. The axis controller can maintain the phis signal. Unit delays are provided Sample and hold with one sample period delay.

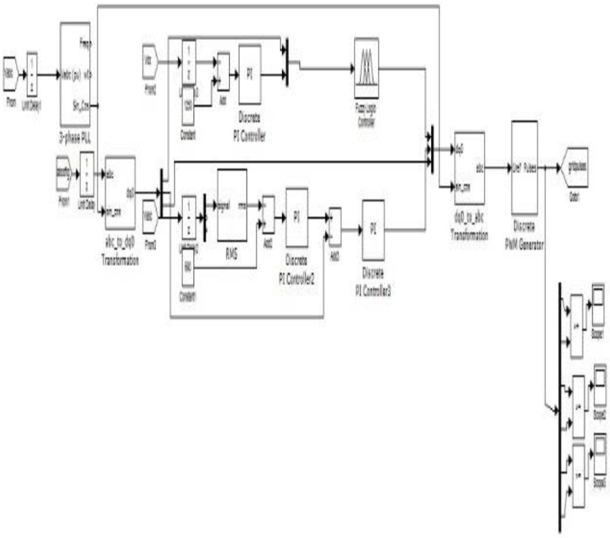


Fig 7: Grid Side Control By Fuzzy Logic Controller

The generated flux from rotor pitch control and phis are compared and the signal is converted into our required format by utilizing the data type converter. The generated torque from stator and generated torque from rotor is compared it produce error signal which is given to torque hysteresis regulator. Where relays, data type functions, logic functions and band controllers are provided to regulate the current levels in two blocks such as stator and rotor.

These three signals are again compared with relation operators with the threshold conditions and it can generate the firing pulses for the rotor side three phase voltage source converters.

The fuzzy logic controller is presented to control the grid side three phase voltage source converters. The PLL blocks are provided to produce grid side three phase voltage with a proper phase sequences and phase differences.

The fuzzy logic controller which can control the dc-link capacitance voltage. The reference dc voltage is compared by the measured voltage and it delivers some error signals because of voltage dip problems. The Fuzzy logic controllers to compensate the errors by identifying problems and compensate the problems by membership functions with fuzzy rules.

In this abc-dqo transmission is presented at stator side to reduce the calculations by converting the three phase system into two phase system. RMS block is used to value is calculated over a running window of one cycle of the specified frequency.

The PI controller are utilized to reduce the steady state and transient errors and improves the stability of the system. Dq-abc transmission technique to convert two phase system by required three phase models from the fuzzy controllers and pi controllers. PWM generators provided to produce the firing pulses for the grid side converters.

A. Fuzzy Logic Controllers:

In FLC, essential control activity is controlled by an arrangement of linguistic principles. These principles are controlled by the framework. Since the numerical variables are changed over into linguistic variables, scientific displaying of the framework is not required in FC. The FLC involves three sections: Fuzzification, interference engine and Defuzzification. The fuzzy controller shown in fig 8.

The FC is characterized as i. seven fuzzy sets for each input and output. ii. Triangular membership functions for simplicity. iii. Fuzzification using continuous universe of discourse. iv. Implication using Mamdani's, 'min' operator. v. Defuzzification using the height method.

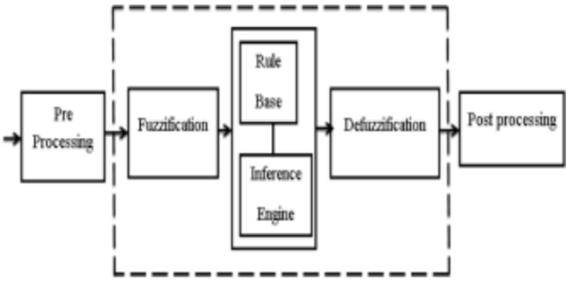
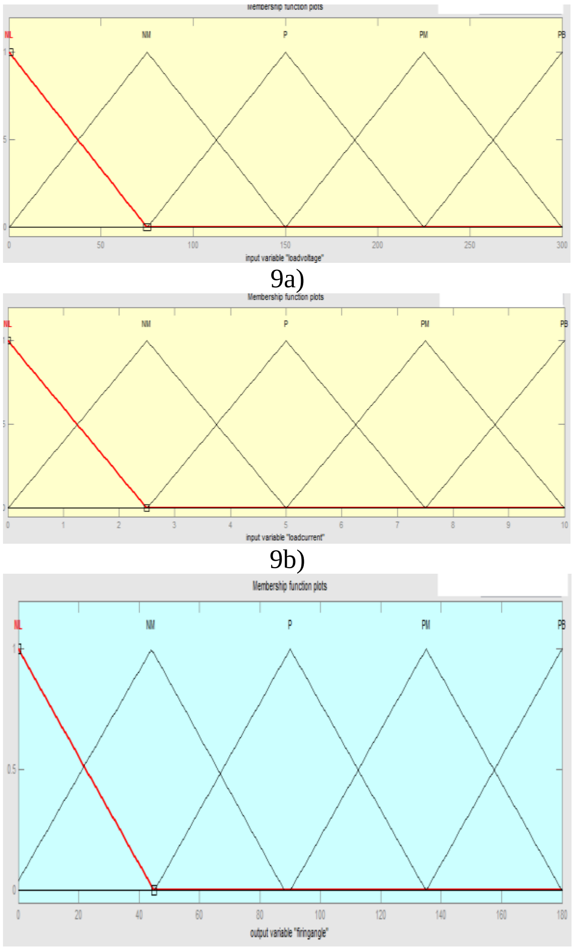


Fig. 8 Fuzzy Logic Controller

1) Fuzzification:

Membership capacity qualities are appointed to the linguistic principles utilizing five fuzzy subsets: NL (Negative low), NM (Negative Medium), P (positive), PM (Positive Medium), and PB (Positive Big).

The partition of fuzzy subsets and the state of participation CE (k) E(k) capacity adjust the shape up to fitting framework. The estimation of information mistake and change in blunder are standardized by a data scaling component.



9a)

9b)

9c)

Fig 9: Fuzzy Logic Controller Membership Functions. A) Input Functions E B) Error Input Function ΔE C) Output Functions

The triangular state of the participation capacity of this plan presumes that for a specific E (k) info there is one and only predominant fuzzy subset. The input error for the FLC is given as

$$E(k) = (Pph(k)-Pph(k-1))/(Vph(k)- V(K-1))$$

$$CE(k) = E(k) – E(k-1) \quad (11)$$

2) Inference Method:

Several piece techniques, for example, Max–Min and Max-Dot have been proposed in the writing. In this paper Min technique is utilized. The yield participation capacity of every guideline is given by the minimum operator and maximum operator.

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3) Defuzzification:

As a plant normally requires a non fuzzy estimation of control, a Defuzzification stage is required. To figure the yield of the FLC, „height" technique is utilized and the FLC yield alters the control required output margins.

E/∆E	NL	NM	P	PM	PB
NL	PB	PB	NM	NM	NL
NM	PB	PB	NM	P	NL
P	P	PM	NM	NM	P
PM	NM	P	NM	NM	PM
PB	NL	NM	NM	NL	NL

Fig 10: Fuzzy Rules For The Proposed System

The generated firing pulsed are given to the back-to converters these are investigated the problems and compensate these by proper firing pulses from the IPC and fuzzy controllers then the voltage dips problems are compensated.

Dc-link capacitance is utilized to store the energy levels at normal conditions and it will releases the energy levels at faulted conditions. Finally it can maintain the constant power from the DFIG by the pitch angle controlling under rotor side control. The generated results are given in below figures.

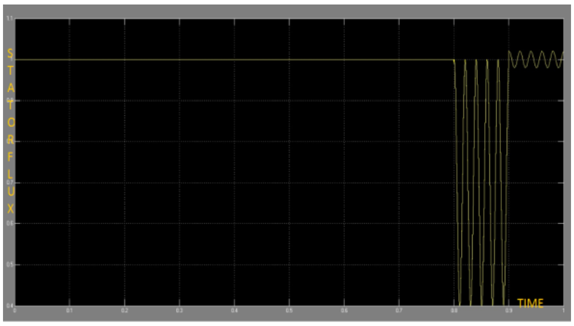

Fig 11: Output Results Of Stator Flux From DFIG

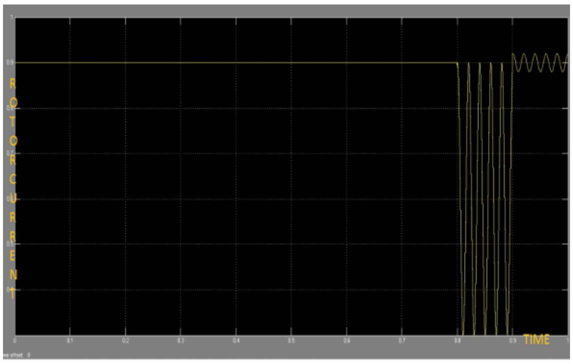

Fig 12: Output Results Of Rotor Flux From DFIG

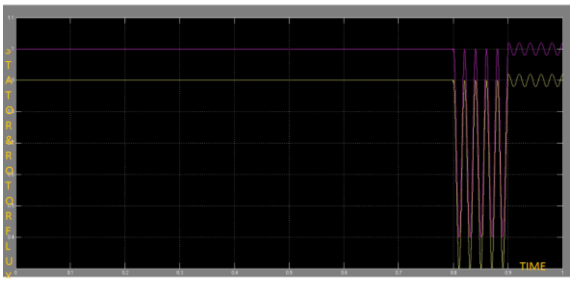

Fig 13: Output Results Of Stator Flux & Rotor Flux From DFIG

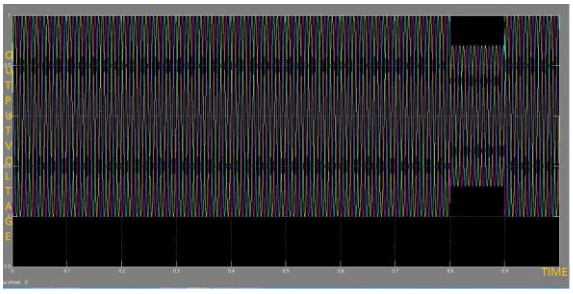

Fig 14: Output Voltage At Load Side From DFIG

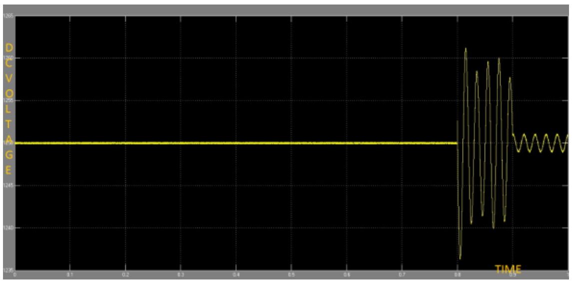

Fig 15: Output Dc Voltage In Back-Back Converter

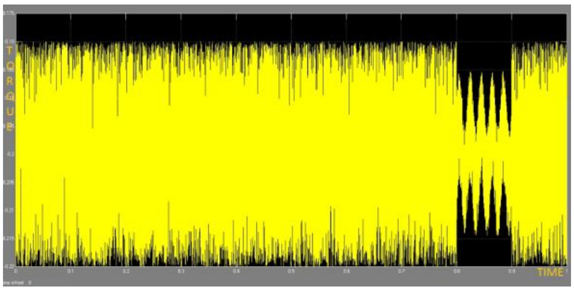

Fig 16: Output Torque From Back-Back Converter

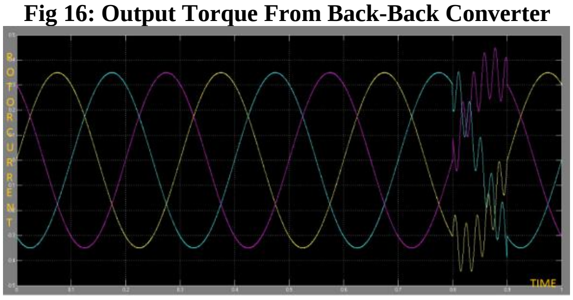

Fig 17: Output Current From DFIG In Rotor Side

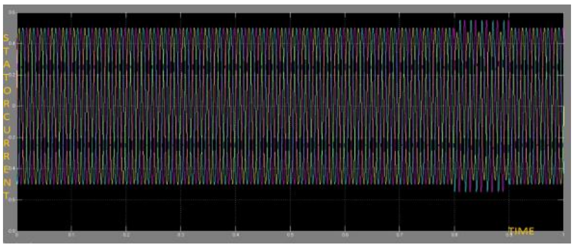

Fig 18: Output Current From DFIG In Stator Side

Parameters	Ratting
Mechanical Torque	10 N.M
Active power	1Kw
Pitch angle	0.2
Flicker Sensitivity	0.26

Table1: Existed Simulation Results

Parameters	Ratting
Stator Pitch Angle	1
Rotor Pitch angle	0.9
Torque	0.18 N.M
Stator current	0.5
Roto r Current	0.3
Load Voltage	1 P.U
Dc Voltage	1260 V

Table1: Proposed Simulation Results

The simulation results are presented in above figures from fig 11-fig 18. These gives the information regarding even in the faulted conditions such as voltage dips detected effectively by utilizing IPC and Fuzzy logic controllers. Finally the system performance enhanced.

IV.CONCLUSION

In this paper demonstrated for the compensation of sag problems by utilizing the IPC controller under different-speed wind turbine applications for the double fed induction generators. In this paper I proposed MW- level DFIG wind turbine based simulation model diagrams are implemented within the MATLAB/SIMULINK. The IPC controller which is used for identification sag problems generation with the presence variable speeds for the wind turbines.

To compensate the sag generations with in the wind turbines I proposed individual pitch angel controller strategy. In this process first we can measure the generation of active power fluctuations they can produce the generation of sags were effectively mitigated by the presence of IPC controller under higher speed and lower speeds from the wind turbines. The integration of fuzzy system with IPC controller we can detect the errors effectively and compensate those errors successfully and hence the system performance is increases.

Here the finalized information for implemented this project produced that the damping active power fluctuations were compensated by the developing of IPC controller for the sags for the adjustable variable speeds from wind turbine under continuous mode of operations. .

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