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Improvement of Control Strategy for Pmsg Based Wecs under Strong Wind Conditions with Anfis Controller

B.Sai Charan Reddy, M.Ram Sekhara Reddy

Abstract**: *Wind farms can only operate and generate power under certain limit of wind speeds if the wind speed is observed beyond the limit then the operation of the wind farm reaches the cutoff region , so in order to operate the wind farm even under strong wind conditions which exceed the limit a control strategy is involved, due to the inability of the PI controller to operate under varying parameters the generated power is affected so in order to adapt a controller that can operate under varying real time parameters a ANFIS controller is adapted in this paper where generated power and d-q axis frame currents are analyzed for linearly rising wind conditions and typhoon landed conditions .***

Keywords **: *PMSG, WECS, ANFIS.***

I. INTRODUCTION

With the increase in the population and the advanced industrialization there has been a huge demand of electrical energy to be supplied to various sectors around the world, as the conventional methods of generating electricity has been limited to their resources so in order to generate the needed power new methods has to be found to generate the power in this search the extraction of electrical energy from renewable energy sources has been found the sources of such kind of energy are wind, solar, biomass, tidal, wave energy. Wind energy is considered to be the most exploitable one among them all. The conversion of the wind energy can be done as the kinetic energy in the wind is converted into mechanical energy and then the mechanical energy is converted into the electrical energy, usually the conversion of the kinetic energy in the wind is converted into the mechanical energy with the help of a turbine and there are two types of wind turbines they are VSWT (variable speed wind turbine) and CSWT (constant speed wind turbine). The CSWT is generally used for constant wind conversion and they cannot adapt to varying wind conditions, on the other hand VSWT can adapt to varying wind conditions. The PMSG is used as the generator for the conversion of mechanical energy to electrical energy it is used because it is robust and involves less maintenance, and the main advantage of PMSG is it can act as a direct drive train which doesn't involve the use of a gearbox which decreases the weight of the machine, In order to obtain direct drive a AC/DC/AC power conversion is used for the WECS based on PMSG in the analysis followedThe wind energy is unpredictable sometimes the wind speeds might exceed their limits of operation of a WECS i.e. from 5m/s to 25m/s, when WECS experience the speeds exceeding 25m/s it undergoes stall condition although new methods of pitch angle control have been introduced the stress on the mechanical parts is the main concern and is unnoticed in the analysis, so in order to have a controlled operation for wind speeds that exceeds the limit and operate the system up to 35m/s, a control strategy involving systems that can effectively control and operate the WECS up to a certain time in this operation the generated power is subjected to disturbances which is caused by the inability of the PI controller to sudden varying changes so in order to process the varying signals and generated power a ANFIS controller has been used in the d-q axis control system of the control strategy, the outputs of the system involving d-q axis control system containing PI controller and the system containing ANFIS controller are evaluated and the simulation is done in MATLAB.

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II. METHODOLOGY

The single line diagram of the wind generation system based on PMSG considered is shown in the figure below the frequency of generated power is variable in nature the generated power is supplied to the grid in fixed frequency and the part from the MSC is considered as a source of voltage.

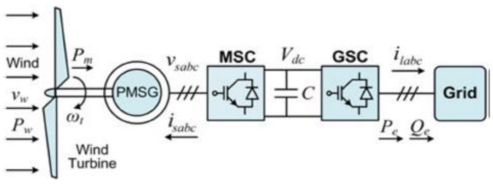

Fig.1. One line diagram of PMSG based WECS

A. Wind turbine aerodynamics

The generated mechanical output power by the wind turbine is given as

$$P_m = \frac{1}{2}\rho A_r v_w^3 C_p(\lambda, \beta) \quad (1)$$

$$\lambda = \frac{w_t R}{v_m} \quad (2)$$

B. PMSG MODEL

C. *The 3phase time varying quantities like stator voltage and current are converted to 2 phase quantities by using parks transformation to easily calculate the quantities and these acquired quantities are sent through the d-q axis frame to process the feedback to be given to the converter the equation of the d-q axis currents & voltages for the PMSG are given as below.*

$$v_{ds} = r_a i_{ds} + L_d \frac{d}{dt} i_{ds} - \omega L_q i_{qs} \quad (3)$$

$$v_{qs} = r_a i_{qs} + L_q \frac{d}{dt} i_{qs} + L_d \omega i_{ds} + \omega \psi \quad (4)$$

Where, v_{ds} = stator voltage in d-axis

v_{qs} = stator voltage in q-axis

i_{ds} = stator current in d-axis

i_{qs} = stator current in q-axis

$L_d = L_q = L_s$ = Stator Inductance

ω = synchronous speed of stator

ψ = Rotor's magnetic flux linkage

The equation for the motion is given as

$$J\frac{d\omega}{dt} = T_m - T_e - B\omega. \quad (5)$$

C. CONTROL STRATEGY FOR THE POWER GENERATION

In the wecs control strategy defines the operation of the wind turbine it sets up a rule for the system on operation conditions the control strategy that is used normally in the wind turbines allows the operating limits of the turbine from 5m/s to 25m/s as shown in the figure below in dotted lines which is the conventional method usually in the wecs control by pitch angle is used to maintain the output power as constant and MPPT control is used to produce the maximum power possible the operation of the wind turbine will continue only up to 25m/s after that the machine is automatically turned off. In the proposed system the control strategy has a different operational limits and the power output of generation holds until a certain wind speed i.e.,35m/s as shown in the fig.2.

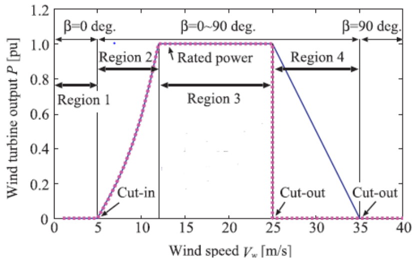

Fig.2. Control strategy diagram

This strategy of control lets the system operate beyond the conventional limits for obtaining this strategy pitch angle control is aided with control of rotational speed which allows the operation of the turbine to have low speed with increasing wind conditions.The parts of the assumed control system used in the proposed model are as follows:

Rotational speed and torque control system

In this system the reference and the measured rotational speeds are processed and the q-axis current which is a reference value is passed to the d-q axis current control system and the direct axis current value is obtained from reference

Active power control system

In this system the reference power generated is obtained from processing the input rotational speed which is a rated value and the output of the controller the controller main controller main purpose is control by power suppression and can handle the generation of power for varying wind conditions.

d-q axis control system

In the d-q axis control system the outputs of the rotational speed and torque control system i.e., the reference d-axis current and the reference q-axis currents are processed in the reference system considered these signals are processed through the PI controller in the proposed system these are processed by a ANFIS controller.

III. EXTENSION SYSTEM

A. ANFIS Controller

ANFIS controller is a fused technique of neural networks and the fuzzy logic technique which is characterized as fuzzification, rule base and the deuzzification the input to the fuzzy logic is provided from input and the output data bases where the input and the output data are linguistic variables the neural network used in the ANFIS system can vary from the type of case considered and the net used in this paper is multilayered feed forward neural network, the ANFIS considered is shown in the figure below.

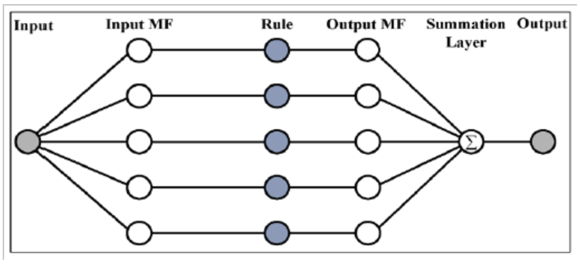

Fig.3. Model Structure of ANFIS

This has one output and the input the variables of the membership function are named as negatively small, negatively big, zero, positively big, positively big are the variables and a triangular wave membership function is created from the variables considered and IF..THEN.. logic is considered for the ANFIS as shown in the table below

IF input is	THEN output is
NB	MF-1
NS	MF-2
Z	MF-3
PS	MF-4
PB	MF-5

Fig.4. Logic in Rule Base

At the output of the ANFIS the output is obtained as a crisp set value after defuzzification the neural net weigh is continued to alter until the error value at the output is zero.

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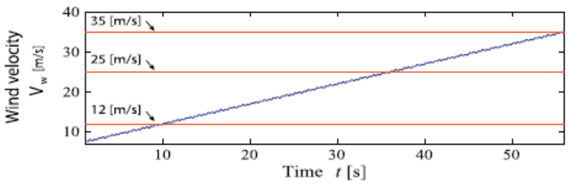
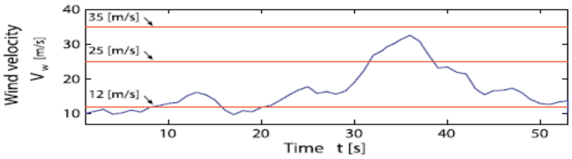
IV. SIMULATION RESULTS AND DISCUSSION OF THE WIND ENERGY GENERATION SYSTEM

The main aim of this project is to see the difference between the PI & ANFIS controller performance in generating the direct and quadrature axis currents in the wind generation system so the evaluation is done under strong wind conditions under strong wind conditions two types of wind conditions are considered they are linearly rising wind conditions and the other is storm landed condition in the linearly rising wind condition the wind rises linearly according to the time the wind conditions are raised linearly up to 35m/s and are presented as a input to the wind turbine and under a storm landed conditions the wind velocity per tie cannot be calculated precisely as different velocities are expected with respect to the time so a empirical high wind conditions which raise and fall abruptly are considered here these conditions are shown in fig.5.



(a) linearly rising wind velocity



(b) Typhoon Landed wind Velocity

Fig.5.Input wind conditions for the wecs

The base system considered uses a PI controller in the d-q axis control system to process the inputs of d, q axis currents and the reference d, q axis currents the system block diagram is as shown in Fig.6.

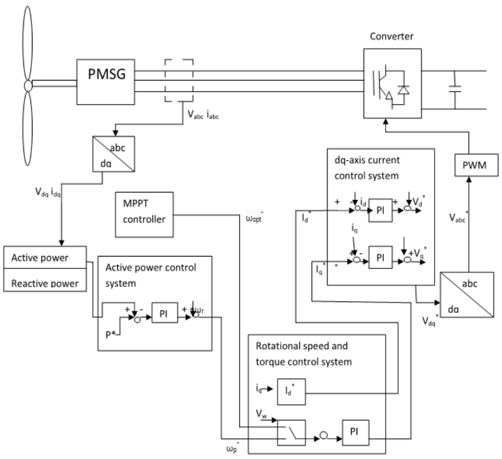


Fig.6. Block diagram of the base system

For the proposed model which uses a ANFIS controller in d, q axis control system to process signals from d ,q axis currents and their respective currents the block diagram of the system considered is shown in the fig.7.

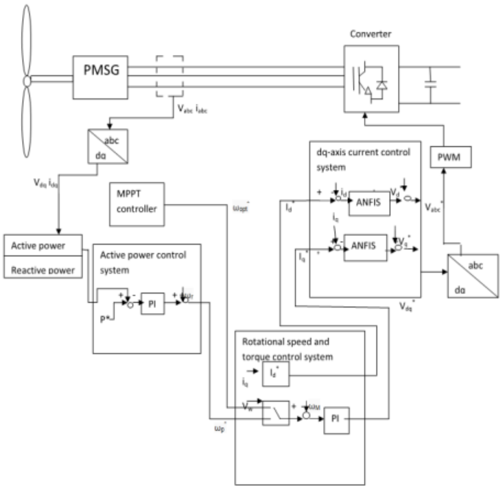
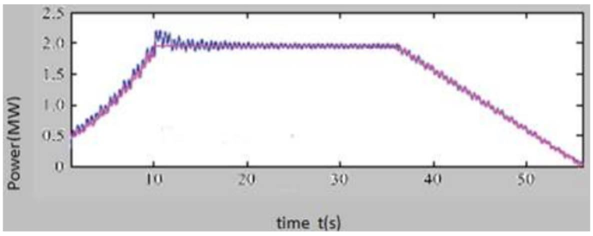


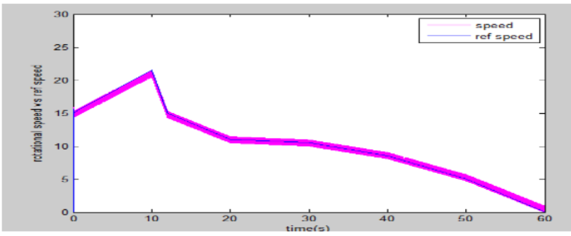
Fig.7.Block diagram of the proposed system

A. Working of WECS under linearly rising wind condition

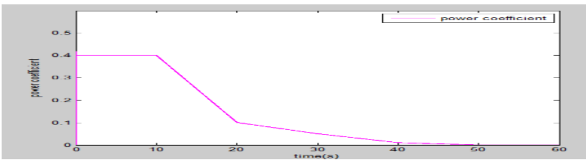
In this case the block diagram of the wind energy conversion system considered here is as shown in the fig.6. Here the input wind conditions considered are linearly rising wind condition the simulated currents and power generated are as shown in fig.8, this system uses a PI controller in the d-q axis frame to process the signals



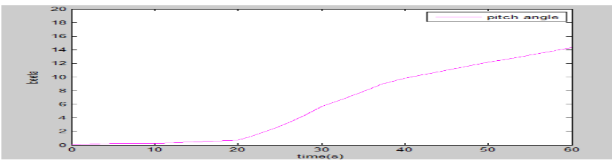
(a)generated power of the wecs



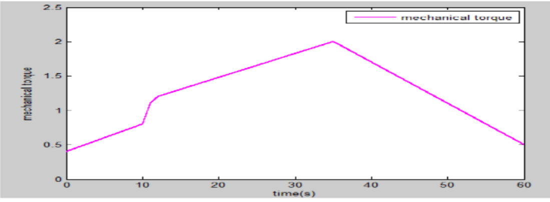
(b) mechanical rotational speed



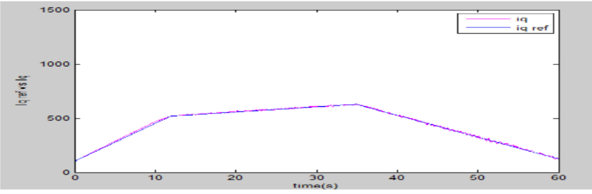
(c)power coefficient



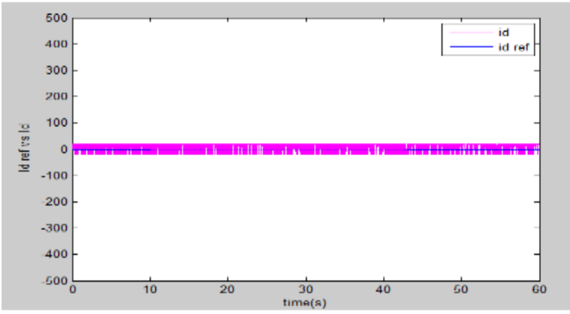
(d)pitch angle



(e)mechanical torque



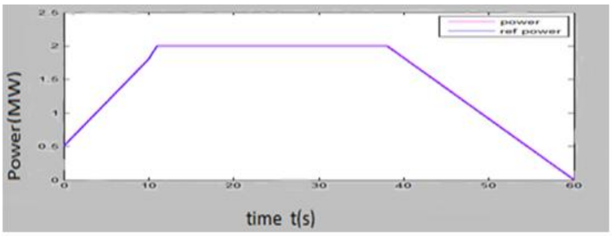
(f)q-axis current



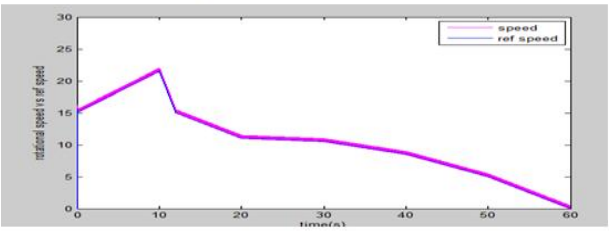
(g)d-axis current

Fig.8.Simulation results of base system for linearly rising strong wind conditions

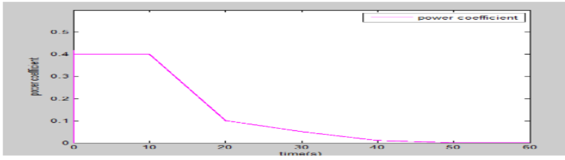
For the linearly rising wind conditions the control strategy involving a ANFIS controller the system block diagram considered is as shown in fig.7. the output results are simulated as



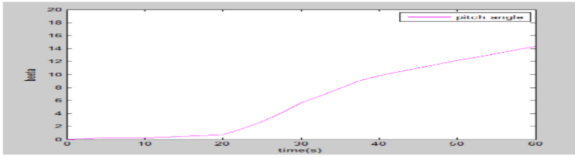
(a)generated power of the wecs



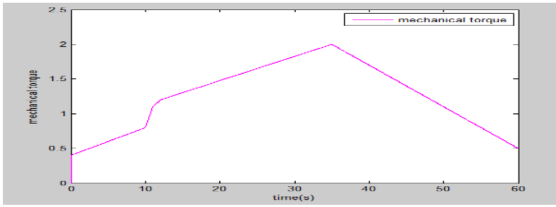
(b) Mechanical rotational speed



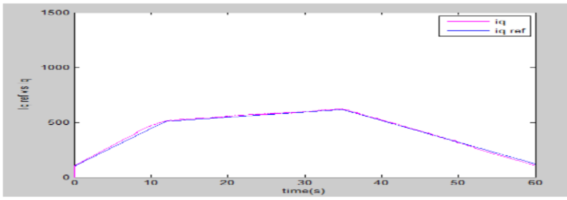
(c)power coefficient



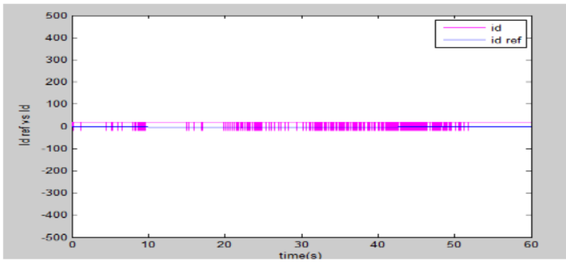
(d)pitch angle



(e)mechanical torque



(f)q-axis current



(g)d-axis current

Fig.9.Simulation results of proposed system for linearly rising strong wind conditions

On evaluating the results of both the controllers and their performance in the control strategy of WECS there has been a reduction in disturbance effects of the power generated and the d-axis currents with ANFIS controller in the d-q axis reference frame.

B. Working of WECS under Storm landed condition

In this conditions the input to the wind turbine is unpredicted so the wind turbine should adopt to varied wind conditions and aid the generation of power this can be done by continuously varying the pitch angle to the varying wind conditions and controlling the rotational speed and torque of the generator the varied response for the assumed system with PI controller and the proposed ANFIS controller responses are evaluated as below
evaluated as below

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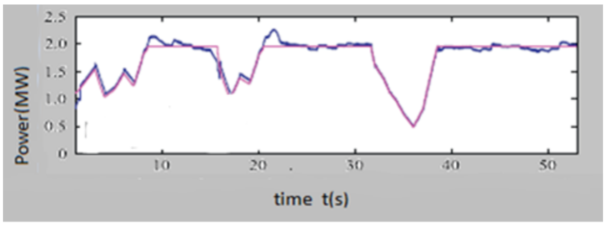
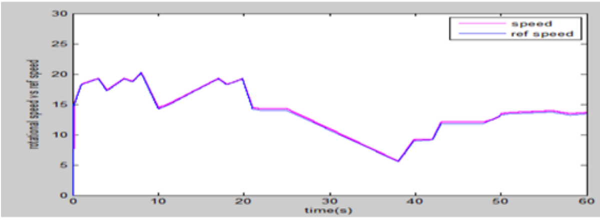
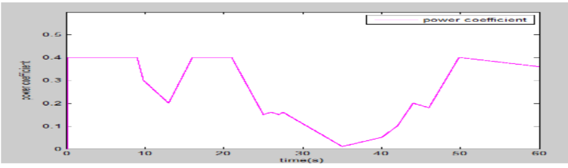


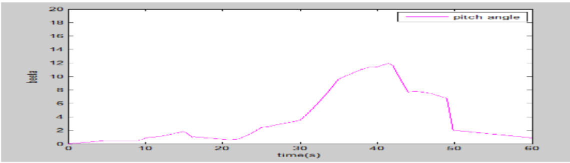
(a)generated power of the wecs



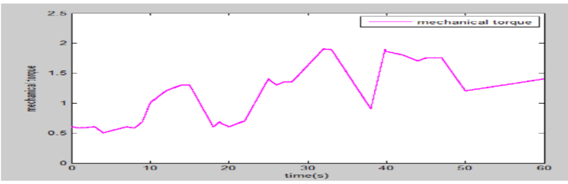
(b) Mechanical rotational speed



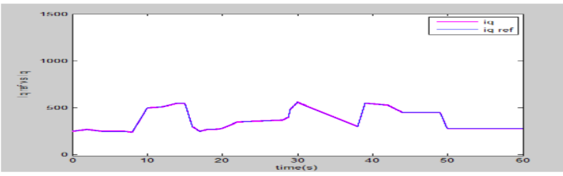
(c)power coefficient



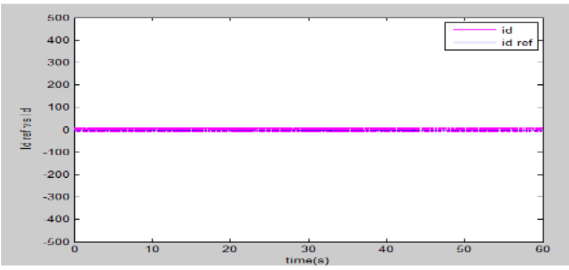
(d)pitch angle



(e)mechanical torque



(f)q-axis current

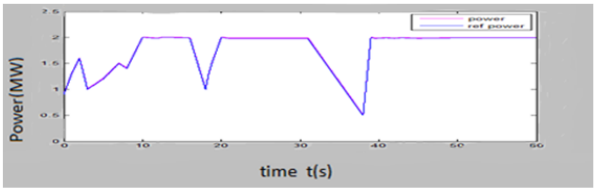


(g)d-axis current

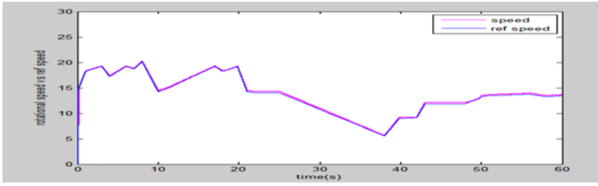
Fig.10. Simulated results of base system for typhoon landed conditions

As we can observe from the above waveforms that there is a change in the waveforms of that of generated power, d-q axis currents when considered with that of the linearly rising wind conditions as the input winds are uncertain in this conditions there is a huge stress on the system operation due to unknown and varying parameters of wind at the input so the generated power is also uneven but there is a expected power generation at the high uncertain winds with an effective control.

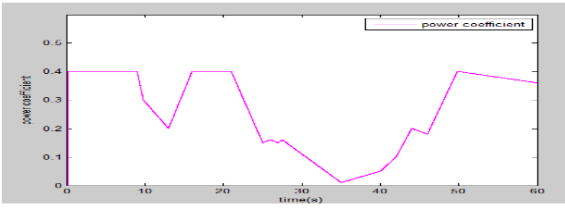
The system response for a controller like ANFIS which has the advantage to adapt to varying parameters unlike the PI controller used above the simulation results are considered and compared as below the system block diagram is as shown in fig.7.



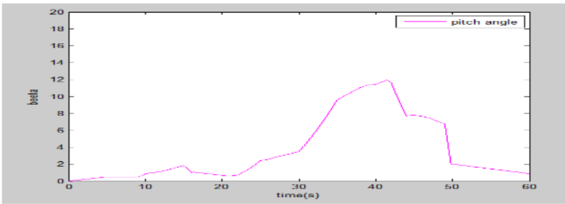
(a)generated power of the wecs



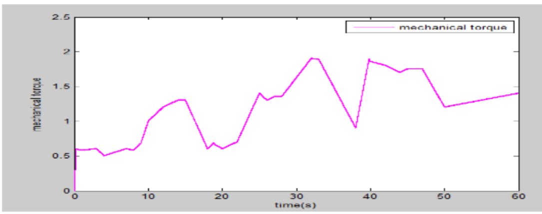
(b) Mechanical rotational speed



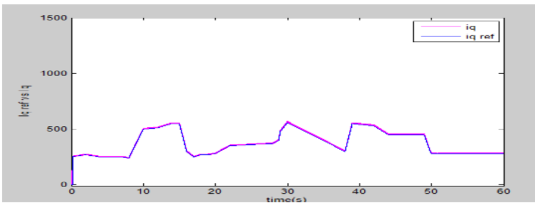
(c)power coefficient



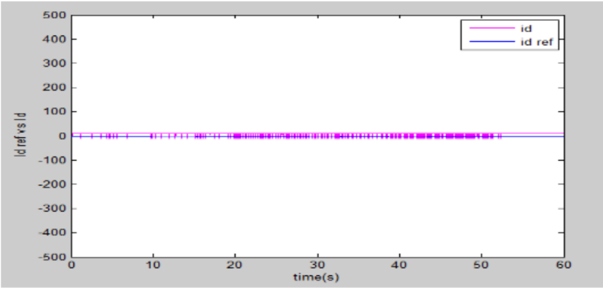
(d)pitch angle



(e)mechanical torque



(f)q-axis current



(g)d-axis current

Fig.11.Simulation results of proposed system for typhoon landed strong wind conditions

Analyzing the waveforms of the system under storm landed condition both the controllers operate at high wind conditions but the generated power on the wind generating fed by the signals processed from the PI controller show the difficulty to adopt to the varying conditions this can be said from the disturbance effect in the power generated and the d-q axis currents generated.

V. CONCLUSION

This paper proposes a control strategy that involves the use of a ANFIS controller in the d-q axis reference frame to process the signals the performance characteristics of using a PI controller are also considered In this paper the wind energy conversion system is tested under two strong wind conditions as linearly rising and storm landed conditions. The power generated from the wind generation system the outputs of the systems using PI controller in the d-q axis frame show disturbances in the waveforms due to its inability to adopt to varying parameters where as in the wind generation system involving ANFIS controller in the d-q axis frame show the reduced disturbance effects than the previous one the control strategy adapted lets the operation of the wind generation at a higher speeds of 35m/s for a certain time instead of the sudden cutoff of wind turbines at 25m/s which is a conventional method .

APPENDIX

The input simulation parameters to the wind power generation system is taken from the base model considered they are.

Parameters of wind turbine	
Blade radius R	38 m
Air density ρ	1.205 kg/m^3
Rated wind speed V_{w_rated}	12 m/s
Optimal tip speed ratio λ_{opt}	0.187
Parameters of PMSG	
Rated output P_{rated}	2 MW
Resistance R_a	50 $\mu\Omega$
d axis inductance L_d	5.5 mH
q axis inductance L_q	3.75 mH
Number of pole pairs p	11
Field flux K	136.25 V·s/rad
Inertia J	10,000 kg·m^2

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