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Controlling and Analysis of Variable Wind Speed Turbine with DFIG Using Fuzzy Logic Controller

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Abstract: *Wind power is growing source in this era of power generation from renewable sources. In India, the power generation from wind is 32562 MW in July 2017 and target for 2022 is 60,000 MW.*
The problems in front of controllers are the variable nature of wind speed that changes the output power of generator. Authors present various controllers, which works on different generators as synchronous and asynchronous generators. The proposed work based on using doubly Fed Induction Generators (DFIG) with wind turbine and controlling its various parameters to obtain stability in output active power. To resolve variable speed problem, Fuzzy Logic Controller (FLC) replaces conventional controller. The parameters considered for controlling are rotor speed, grid voltage and rotor voltage. By controlling these parameters active power, reactive power, rotor speed, torque, line current and voltage are controlled. FLC implemented in converter controlling and the DC link Capacitor connected for power sharing. Wide range of FLC provides variation is control parameters as wind speed varies so that the generator receives constant torque and stable rotor speed. The system implemented is of 9MW DFIG generator with 47 MVA/ 230KV load. Wind speed is taken variable form 12 m/s to 16 m/s and system is in pu. The system designed in MATLAB/SIMULINK.
Keywords: *doubly fed induction generator (DFIG), Fuzzy logic controller (FLC).*

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I. Introduction

Now a day's electrical power is a part of everyone's life. As the demand of power increasing, the requirement to generate power is also increasing. The most available sources are solar and wind. Both of these power plants need a specific requirement of location where the plant have to setup.

Major disadvantage of these resources are their low efficiency generation and variable in nature. This is due to economic reasons, that if efficiency will be increases then total power plant equipment will be more costly than the total generation. In this paper, wind energy source is considered for research and analysis. Total power generated from wind in this world is 12 % (approx. 486.8 GW) where as in India its 9.1% (approx. 33,000 MW) of total power generation up to 2017[1,2]. In fig.1, the data showing the present situation of installed units in India up to 2016.It shows that the maximum units is installed in Tamil Nadu (7694.3 MW) and achieved target of 32562 MW in 2017.the proposed installation of wind power by 2022 in india is double the power installed till year.The main thing is its pollution less generation and it is renewable source of energy. Data shows the increasing interests of installing number of units of wind power all over India.

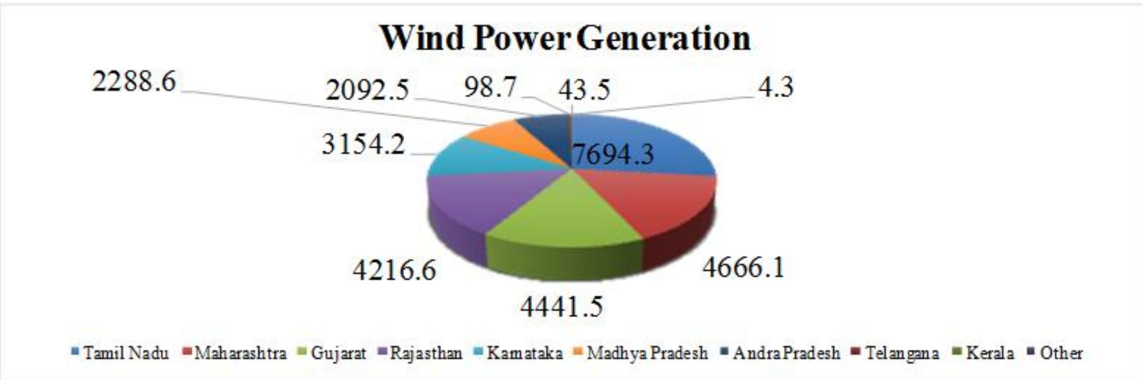

Fig.1 Installed units of wind power in different states of India in MW

As shown in Fig.2 the growth of wind power in year 2012 to 2017 in India. The number of units of wind power is gradually increasing all over India due to its many benefits mentioned in next point [1, 2].

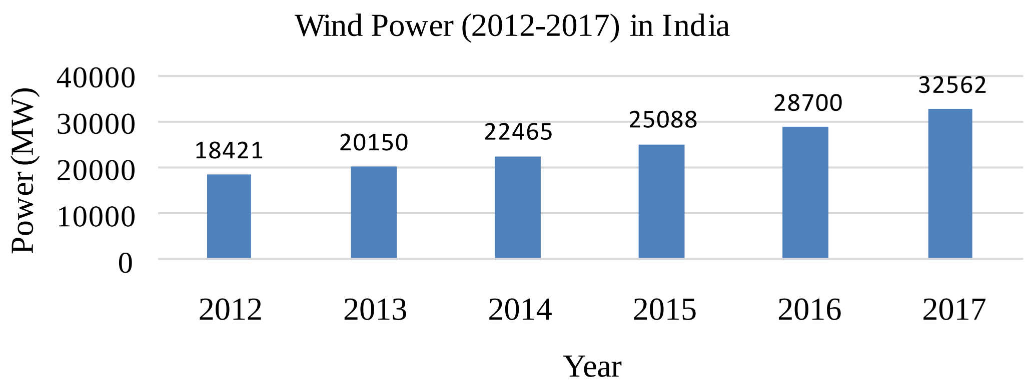

Fig. 2 Data of India cumulative installed wind capacity

II. DOUBLY FED INDUCTION GENERATOR (DFIG)

DFIG is an asynchronous generator, which is connected to grid from both side as grid and rotor using converters coupled with DC link capacitor. Grid side converter controls the voltage coupled with wind turbine rotor side converter controls the current component of generator

The AC/DC/AC convertor divided into two type's component:

1. Rotor side convertor
2. Grid side convertor

These convertors are voltage source convertor (VSC) that uses power electronics devices to synthesize an AC voltage from a DC sources.

For above synchronous speed conditions Rotor power (Pr) output is transmitted to DC bus capacitor and tends to raise DC voltage. In addition, below synchronous speed conditions Rotor power output is taken out of DC bus capacitor and decrease the DC bus voltage [3-6].

The grid side convertor used to generate or absorb the grid reactive power (Qg) in order to keep the DC voltage constant.

By regulation of current through rotor side converter, it regulates active and reactive power of generator. The grid side converter controls the DC link voltage at unity power factor or zero reactive power.

The controllers control the firing angle for converters to control parameters like active, reactive power, Vdc and voltage-current.

III. MODELING OF PROPOSED SYSTEM

Fuzzy logic controller is used with DFIG and comparative results are taken in respect of stability are represented

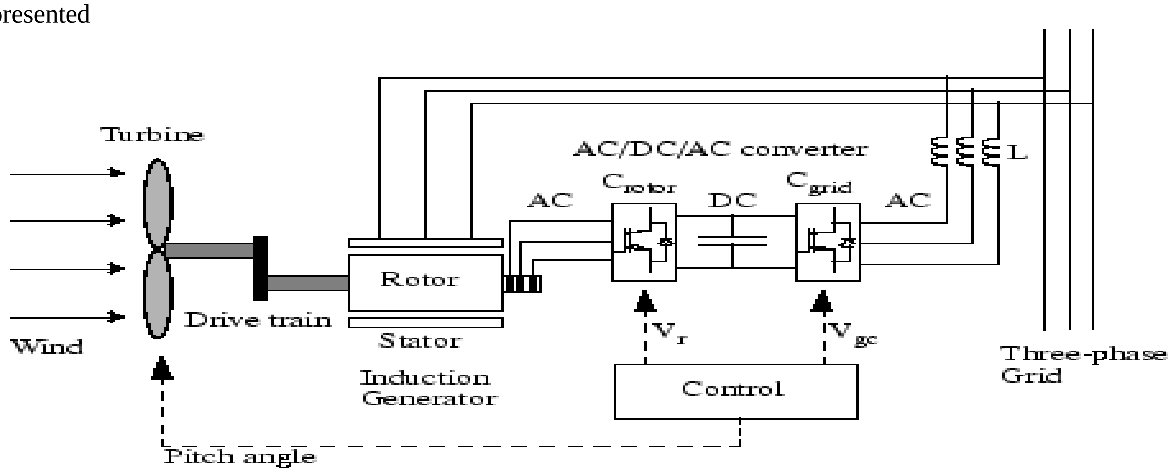

Fig.3 DFIG model with wind base turbine and convertors

Controller is applied to the model shown in Fig.4 and shows below the schematic diagram of proposed power system with wind turbine and (DFIG). Where, DFIG is taken on 9MW generation and load at 47 MVA/230 KV rating [4-8].

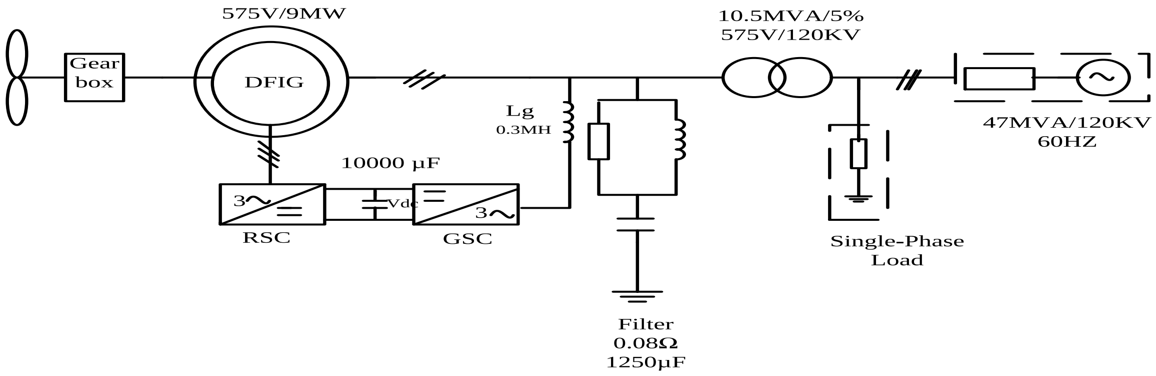

Fig.4 Schematic Diagram of Proposed Power System

Table.1
Parameter for Proposed System

S.no	Generator data for 1 Wind turbine	Rating
1	Nominal Power (MW)	1.5
2	Line to Line Voltage(Sending End)(Vrms)	575
3	Line to Line Voltage(Receiving End)(Vrms)	1975
4	Frequency(Hz)	60
5	Stator [Rs] (p.u.)	0.023
6	Stator [Lls] (p.u.)	0.18
7	Rotor [Rr'] (p.u.)	0.016
8	Rotor [Llr'] (p.u.)	0.16

IV. SIMULATION MODELLING OF WIND TURBINE WITH FLC

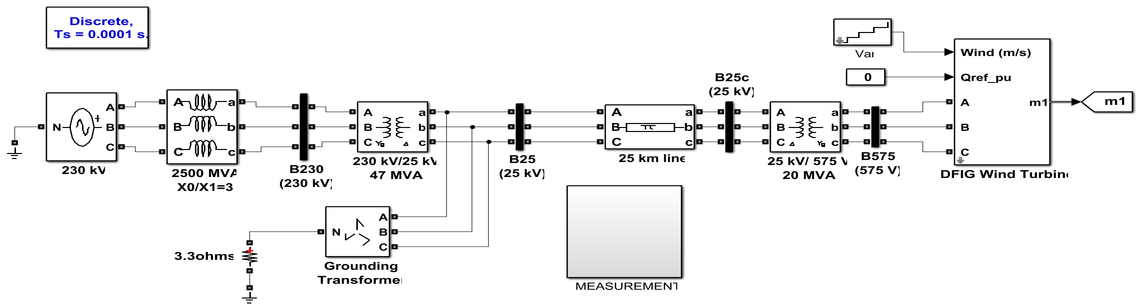

Fig.5 Simulink model of Proposed Power system

The proposed system is designed in MATLAB/SIMULINK with power generation of DFIG with wind turbine with variable wind speed form 12 m/s to 16 m/s.

Fuzzy Logic Controller for controlling of proposed system.

Fig 6 shows the fuzzy interface system for fuzzy logic controller implemented in rotor side converter to control Vdq voltage. The input for this FIS is Id and Iq dq-frame currents and the outputs are Vd and Vq voltage.

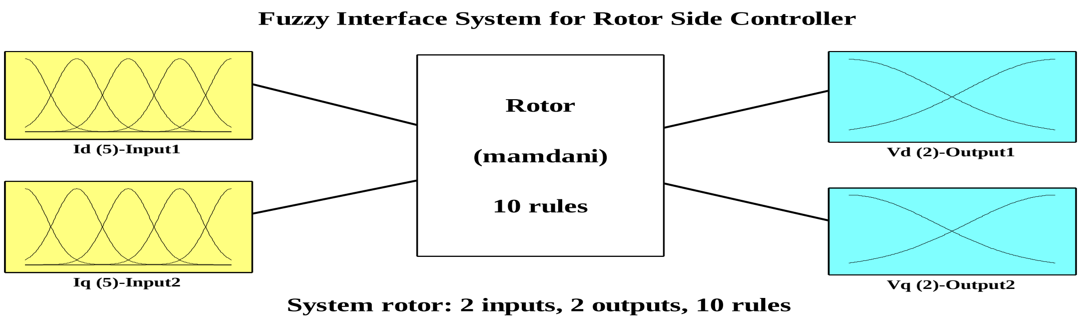

Fig.6 Fuzzy interface system for rotor-side controller.

Fig 7 shows the fuzzy interface system for fuzzy logic controller implemented in speed controller to control speed. The input for this FIS is deviation in rotor speed and the outputs is improved speed

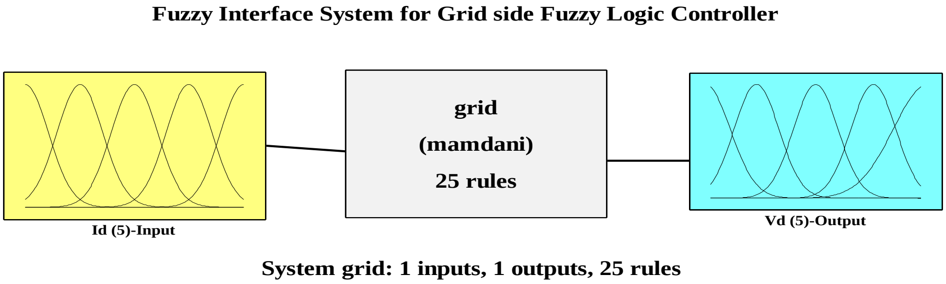

Fig. 7 Fuzzy interface system for speed controller in FLC.

Fig 8 shows the fuzzy interface system for fuzzy logic controller implemented in grid side controller to control voltage. The input for this FIS is d-frame current.

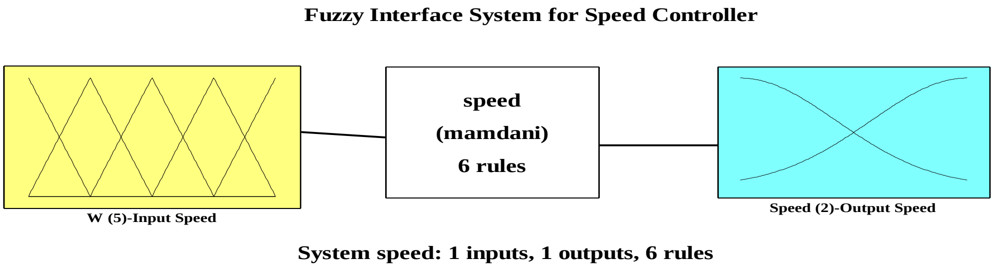

Fig. 8 Fuzzy interface system for grid side controller FLC.

V. RESULTS AND ANALYSIS

This chapter of thesis includes the simulation and results of proposed system in wind turbine with DFIG implementing Fuzzy logic controller. Simulation of proposed system is designed in MATLAB/Simulink.

DFIG with generation gives reasonable results with fuzzy logic controller and gives better stability with proposed technique.

The proposed system is designed with 9 MW DFIG, to work with variable wind speed and fuzzy logic controller for its better performance. The variation in wind speed is taken from 12 m/s to 16 m/s and simulation is operated at 20 Ts so the variation is taken as 12 m/s at Ts, 13 m/s at 3 Ts 14 m/s at 7 Ts, 15 m/s at 12 Ts and 16 m/s at 17 Ts. This variation is taken as by nature, wind is variables and in practical system, it is mandatory to control system in these conditions.

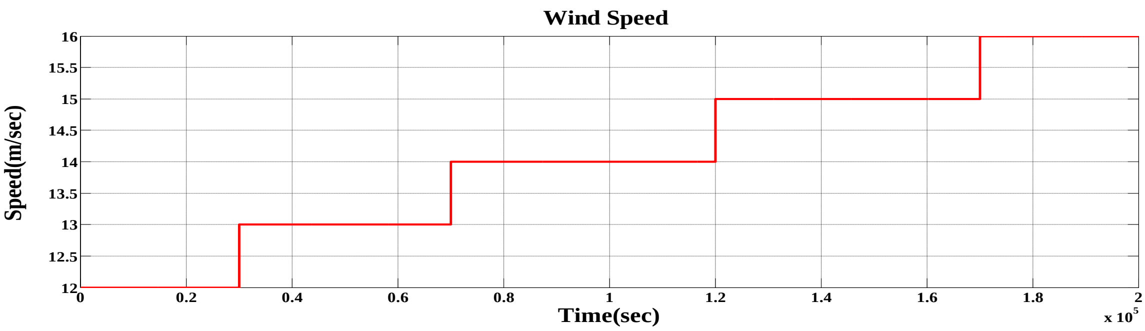

Fig. 9 Output Steps of Variation in Wind Speed.

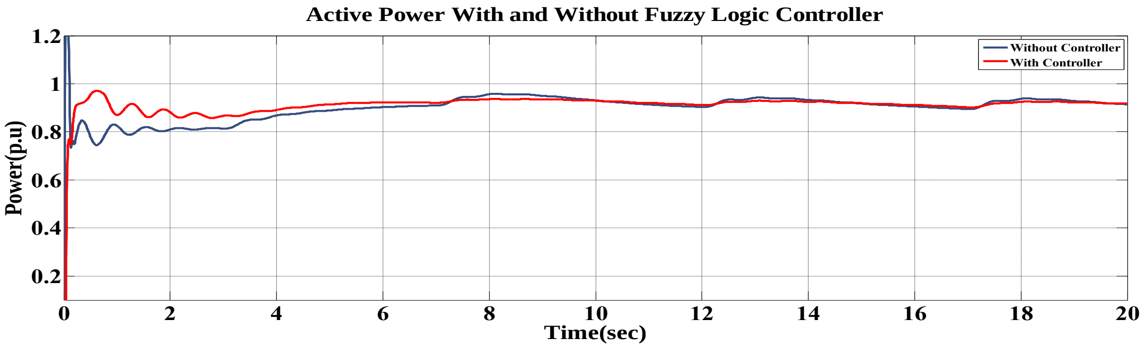

Fig. 10 Output Waveform of Active Power with (FLC) and Without Controller.

As shown in fig. 10 active power output analysis when controller i.e fuzzy logic is connected or not .When it is compared then the outcome is that that when controller is connected at that condition the required active power gets more stable than other. When wind speed get variable at that moment there is variation in power in uncontrolled system but when controller is applied this variation is removed.

Fig. 11 Output Waveform of Reactive Power with and Without Fuzzy Logic Controller.

As shown in fig. 11, Reactive power of system with comparison of proposed system with the system having conventional controller. It is observing that the reactive power is almost O MVAR in both system and the only variation is in its initial values or reaction to the system, where controlled system response is with fewer distortions.

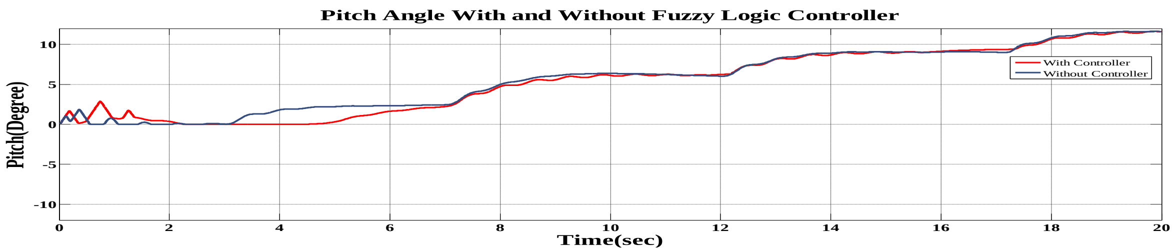

Fig. 12 Output waveform of pitch angle variation with and without fuzzy logic controller.

Pitch angle variation depends on wind speed variations as the speed varies pitch angle also varies. As wind speed is varies from 12 to 16 m/s then pitch angle also varies in step in the system of conventional controller and in proposed system this pitch is controlled to very in continuous from to maintain stability of power. This variation is represented in fig. 12

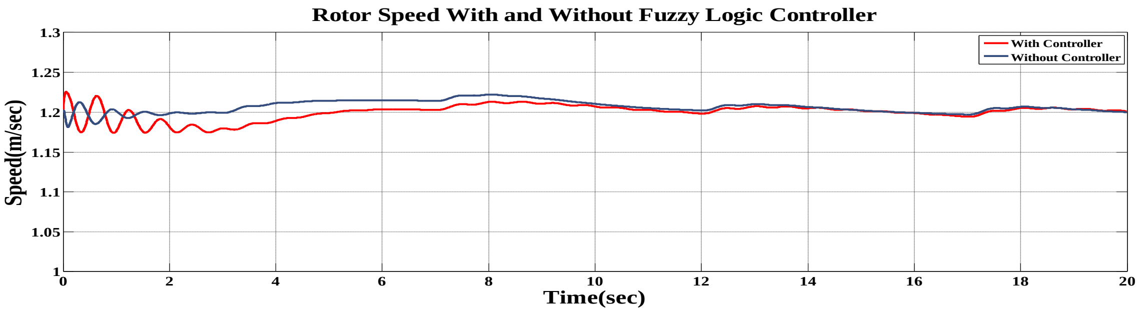

Fig. 13 Output Waveform of Rotor Speed with and Without Fuzzy Logic Controller.

To control output active power, it is required to maintain stability in its rotor speed fig. 13 represents the rotor speed output waveform of proposed system and conventional system. Rotor speed is taken 1.2 pu. as reference and in fuzzy logic controller output it is observed that the result are more towards reference as compared to other method.

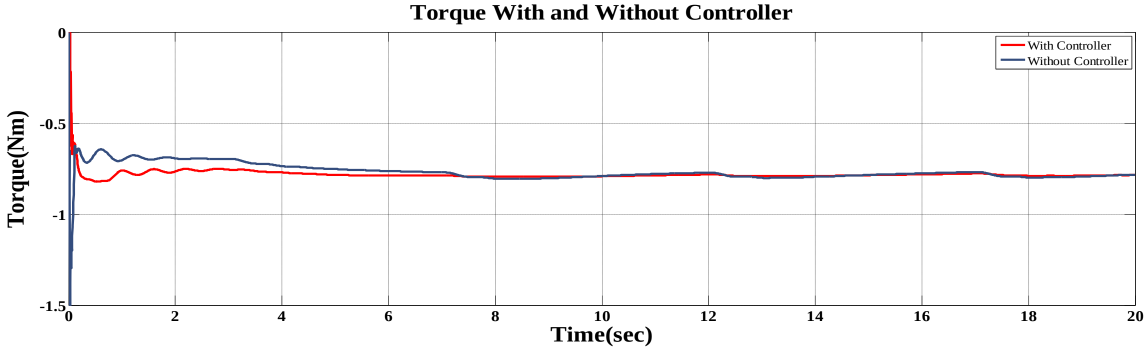

Fig. 14 Output Waveform of Torque with and Without Fuzzy Logic Controller.

Electromagnetic torque must be negative in case of generator and vary as per variation in rotor speed. If rotor speed is kept constant, as it is stable then output torque also gets stable. The same is seen in output waveform of fig.14 output of both systems. However, proposed system is more towards negative value, that shows the active power is towards stability.

DC link capacitive is connected in between rotor side and grid side converter to share active power from rotor side to grid side controller. To maintain shared active power constant this link capacitor must be regulated so the power supplied and controlled by grid side is stable

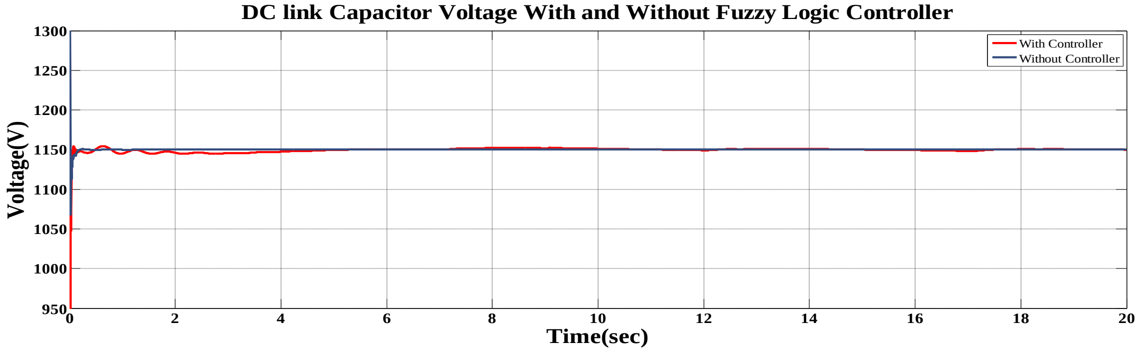

Fig. 15 Output Waveform of DC Link Capacitor Voltage with and Without Fuzzy Logic Controller.

. The active power is transferred to grid load. As shown in fig.15, comparison of both controls. The output of DC link voltage is kept at 1150 V. In FLC this voltage is varying to control receiving power and absorb reactive power for stability. In conventional controller it is seen that this is very much constant to 1150 V.

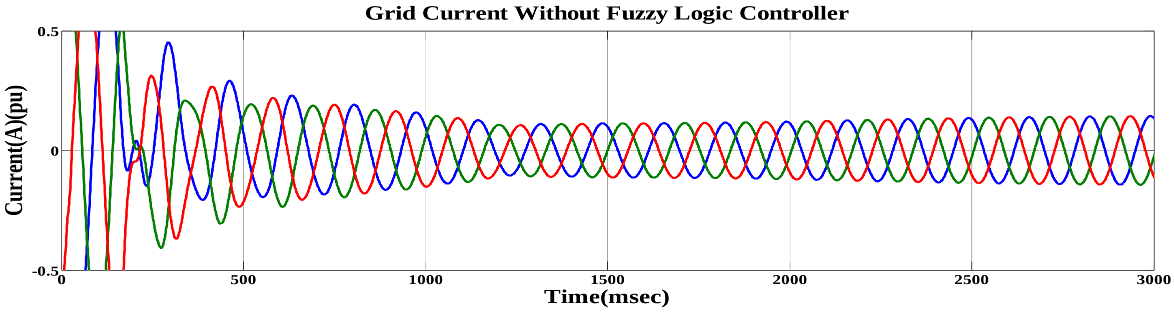

Fig. 16 Output Waveform of Grid Side Converter Without Fuzzy Logic Controller.

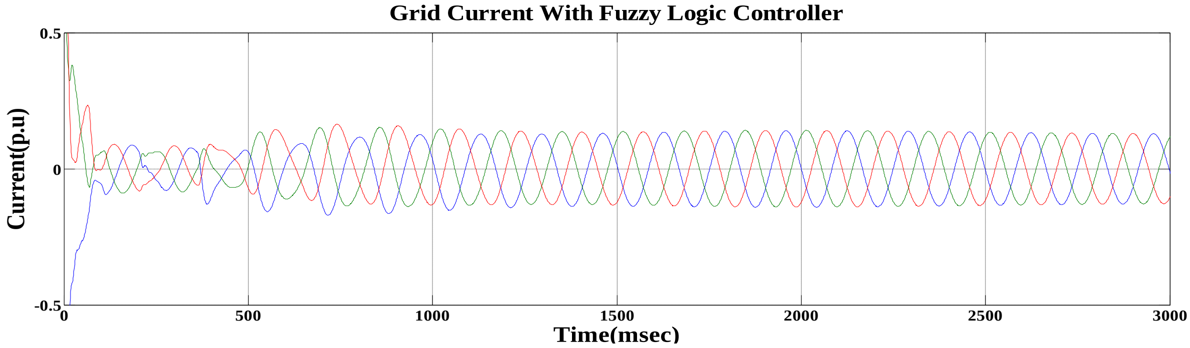

Fig. 17 output waveform of grid side converter to current with fuzzy logic controller.

As shown in fig.16 and fig.17, grid side converter current supplied by grid side controlled to grid and load. From fig.16 it is observed that with conventional controller initial distortion is high as compared to fuzzy logic controller. In proposed system when it is get stable at 500 ms, it is stable at 1000 ms in conventional system controller and having large value of current in initial conditions. This represents that with FLC the system is more stable.

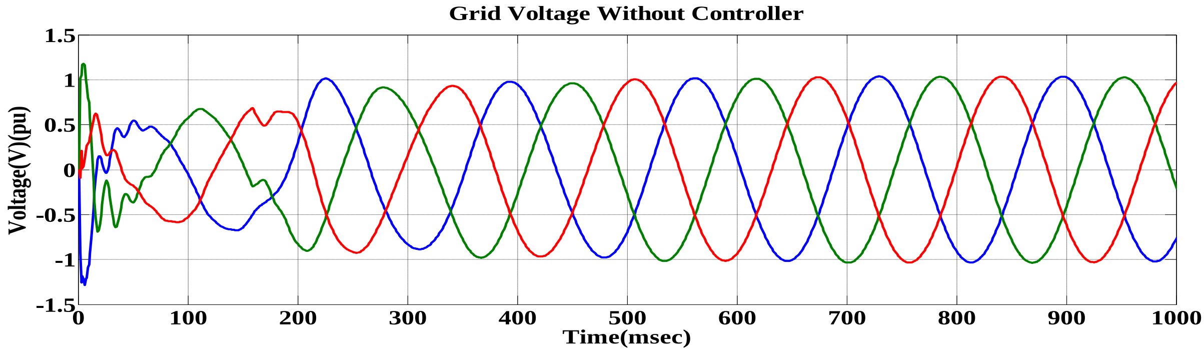

Fig.18 Output Waveform of Grid-Side Converter Voltage Without Controller.

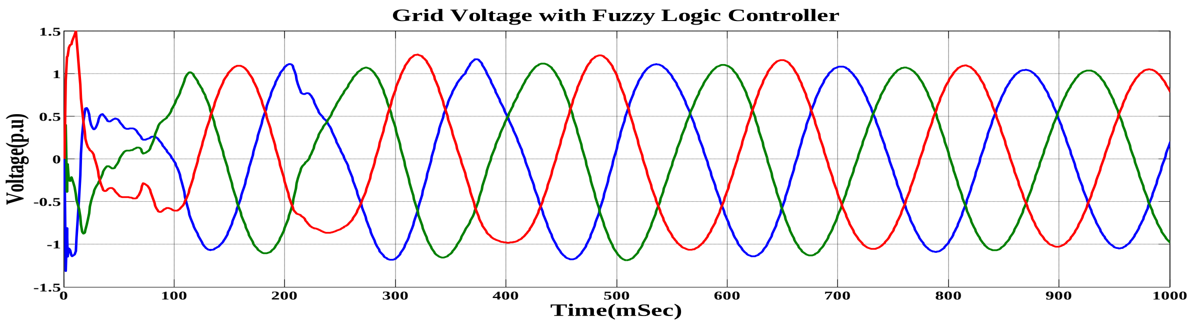

Fig.19 Output Waveform of Grid-Side Converter Voltage with Fuzzy Logic Controller.

From fig.18 and fig.19, it is observed that the distortion in grid-side converter voltage without controller is more as compared to the system having fuzzy logic controller and system is kept in p.u. In conventional system waveform get constant at 200 ms. Where in FLC it comes at 100 ms. This voltage is supplied to grid connected to the system and load.

VI. CONCLUSION

In proposed system wind turbine is connected with DFIG of 9 MW and 47 MVA/230KV load. The system is controlled using Fuzzy Logic Controller and compared with conventional controller for validation of proposed technique. The generator is taken on dq frame reference and on per unit system. The problem of variable output power in variable wind speed condition is considered to resolve by controlling rotor speed, active power, reactive power , torque and DC link voltage.

Three FLC are implemented in grid-Side converter, rotor-side converter and speed regulation. Speed is varied from 12m/s to 16 m/s for 20 Ts time. From Grid-side controller, regulation of DC voltage and current is performed; the FLC used in rotor side controller controls the active and reactive power for grid.

Comparison is presented with output waveforms of various parameters. Analysis of same shows that there is improvement is active power as there is less fluctuation in output and gets constant earlier. Disturbance in reactive power is decreased in initial stage and then get stable near to zero. To control output power and speed pitch is improved to vary and control at every point of variation, it can be observed from its output waveforms. Torque in case of generator is negative and it is receiving in proposed technique. DC link voltage used to share active power in between rotor and grid converters and it is required for getting power stable, so in given technique it is constant and slight variation are seen to maintain sending power constant. The system is designed in MATLAB/Simulink.

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