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Performance Comparison Of Variable Speed Induction Machine Wind Generation System With And Without Fuzzy Logic Controller

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Abstract:
In this paper, we proposed a variable speed induction machine wind generation system with fuzzy logic controller, and make a performance comparison of variable speed induction machine wind generation system with and without fuzzy logic controllers. Artificial intelligence techniques such as fuzzy logic, neural network, and genetic algorithm are recently showing a lot of promise in application of power electronics systems. A squirrel cage induction generator feeds the power to a double-sided pulse width modulation converter system which pumps power to a utility grid or to an autonomous system. The generator speed is controlled by indirect vector control with torque control in its inner loop. The fuzzy logic based control of the system helps to optimize efficiency and enhance performance . a complete 3.5 KW generation system has been designed by using MATLAB.

Key words: *Fuzzy Logic Controller (FLC), Membership Functions(MF)*

1.Introduction

The global electrical energy consumption is rising and there is steady increase of the demand on power generation. The recent sharp increases in the prices of oil, natural gas, uranium and coal underline the importance for all countries to focus on development of alternative energy resources. For developing countries, these price increases can have ruinous economic consequences; for many countries already plagued by poverty this means a choice between fuel and food, health care, education and other essentials. Renewable energy resources need priority because:

- The overwhelming scientific evidence that anthropological emissions of greenhouse gases from carbon combustion threaten catastrophic results from rapid climate change.
- The severe health and environmental consequences from fossil fuel combustion being experienced in every major developing country city.
- The high cost, environmental damages and security threats of nuclear power.

Wind energy for electricity production today is a mature, competitive and virtually pollution-free technology widely used in many areas of the world. Wind also still is used to some extent for pumping water. Wind electric systems have some siting problems involving their aesthetics, and some wind machines have problems with killing raptor birds that fly into the blades, though this problem has been minimized with more modern slower-rotating blades and the siting of wind farms outside raptor flying zones. Wind power is the fastest growing energy technology in the world. Total India-wide capacity was 19,051 MW in 2013 jan31.

2.Overview Of The System

The main objective of this project is to analyze the performance of a variable speed wind generation system by using fuzzy logic principles for efficiency optimization and performance enhancement control, , and make a performance comparison of variable speed induction machine wind generation system with and without fuzzy logic controllers. Developing the wind power production model is a two step process. First the wind speed model has to be created. Subsequently the make of the wind turbine model has to be done. The process is shown on fig.1.

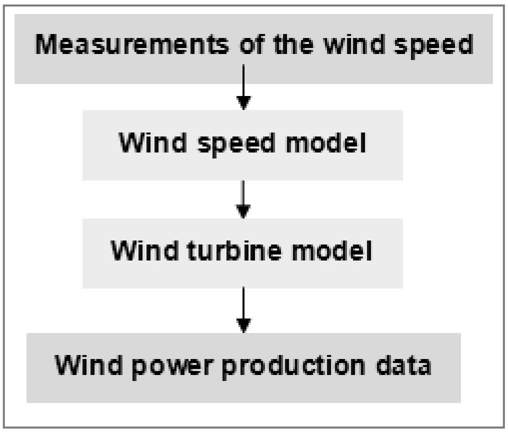

Figure 1: Procedure For Designing The Model For Simulating Wind Power Production

There are two main types of wind turbines: fixed speed and variable speed. Diagrams for the two types of wind turbines are shown on fig.2

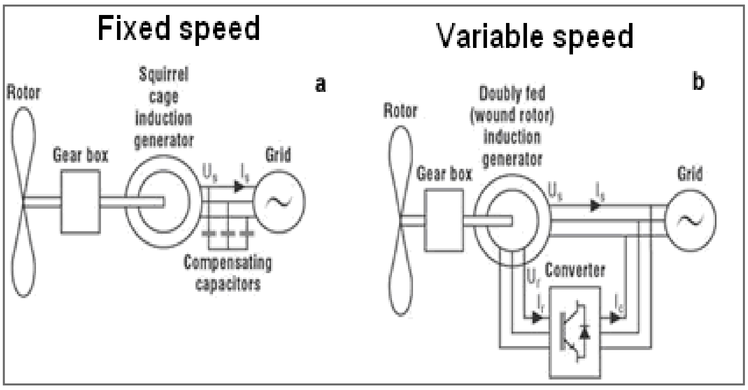

Figure 2: Models Of Fixed Speed And Variable Speed Wind Turbines

The generation system uses three numbers of fuzzy logic controllers.

- The first fuzzy controller tracks the generator speed with the wind velocity to extract maximum power known as Generator speed tracking controller.
- The second fuzzy logic controller, programs machine flux for light load efficiency improvement known as Generator flux programming controller.
- The third fuzzy logic controller, provides robust speed control against wind vortex and turbine oscillatory torque known as Closed loop generator speed controller.

3.Fuzzy Logic Controllers

The heuristic way of searching the maximum could be based on a rule called as "Fuzzy Meta rule", which is given as follows: "If the last change in the input variable (x) has caused the output variable (y) to increase, keep moving the input variable in the same direction; if it has caused the output variable to drop, move it in the opposite direction."
The Wind generation system consists of three no's of fuzzy logic controllers:

3.1.FLC-1 (Generator Speed Tracking Controller)

For a particular wind velocity FLC-1 function is search the generator speed until the system settles down at the maximum power output condition. For wind velocity Vco4 in fig. 4, the output power will be at A if the generator speed is r1. The FLC-1 will alter, the speed in steps until it reaches the speed r2, where the output power is maximum at B. If the wind velocity increases to V©2, the output power will jump to D, and then FLC-1 will bring the operating point to E by Searching the speed to cor4. Similar is the case of decrease in wind velocity. With an incrementation (or decrementation) of speed, the corresponding incrementation (or decrementation) of output p o wer is estimated. The controller operates on a per-unit basis so that the response is insensitive to system variables and the algorithm are universal to any system. The wind vortex and torque ripple can lead the search to be trapped in a minimum which is not global, so the output Ko is added to some amount of L r in order to give some momentum to continue the search and to avoid such local minima[10]. The scale factors KPO and KWR , are generated as a function of generator speed so that the control becomes somewhat insensitive to speed variation.

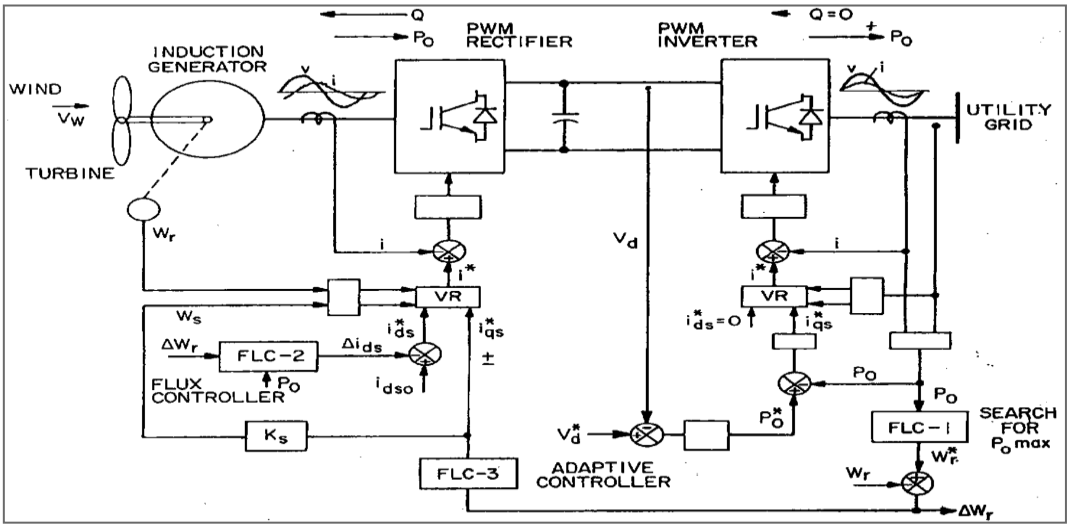

Figure 3: Fuzzy Logic Based Control Block Diagram Of Wind Generation System

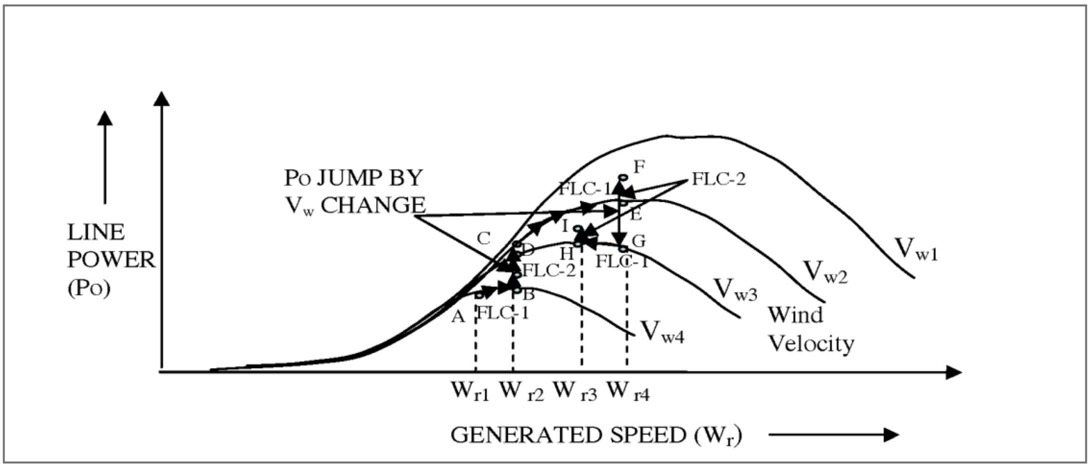

Figure 4: Fuzzy Controllers FLC-1 And FLC-2 Operation Showing Maximization Of Power

The scale factor expressions are given as:

KPO = $a_1 w_r$

KWR = $a_2 w_r$

Where, a1 and a2 are the constant coefficients that are derived from simulation studies. In FLC-1, there are two inputs AP0 and LAcor* and one output Acor* .In the implementation of fuzzy control, the input variables are fuzzified ,the valid control rules are evaluated and combined and finally the output is defuzified to convert to the crisp value. In this paper , the above block diagram of FLC-1 was simulated using triangular membership function and the centroid method was used for defuzzification.

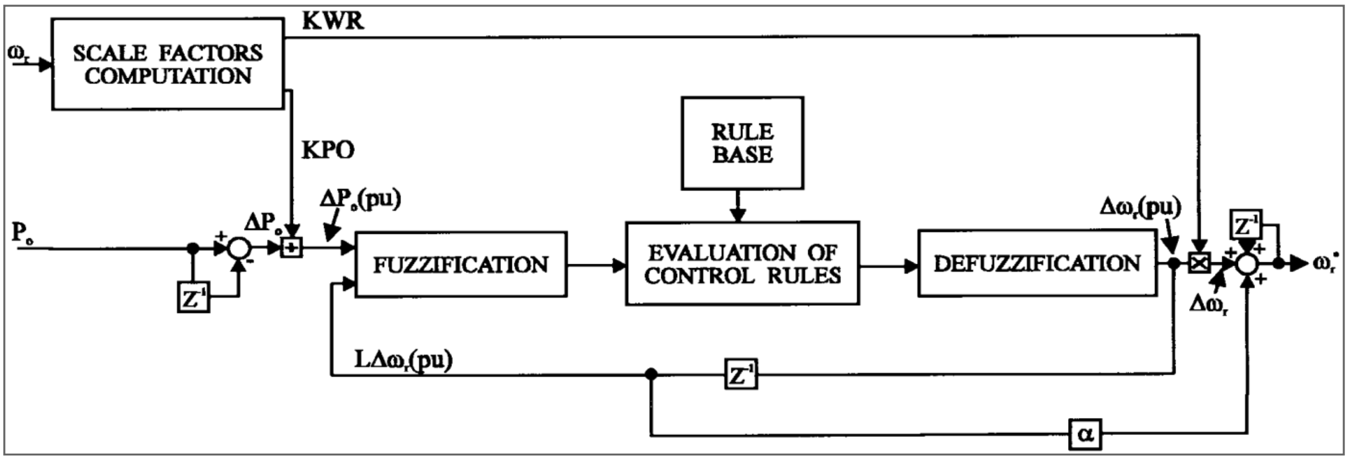

Figure 5: Block Diagram Of FLC-1

$L\Delta W_r^*$ ΔP_o	P	ZE	N
NVB	NVB	NVB	PVB
NB	NB	NVB	PB
NM	NM	NB	PM
NS	NS	NM	PS
ZE	ZE	ZE	ZE
PS	PS	PM	NS
PM	PM	PB	NM
PB	PB	PVB	NB
PVB	PVB	PVB	NVB

Table 1: Rule Matrix For FLC-1

A typical rule of FLC-1 can be read as follows:
"If APo is PM (positive medium) AND LAcor* is P (positive), THEN Acor* is PM (positive medium)."

3.2.FLC-2 (Generator Flux -Programming Controller)

The function of FLC -2 is to program the machine rotor flux for light load efficiency improvement. The block diagram of FLC-2 is shown in fig. 9.The system output power Po(k) is sampled and compared with the previous value Po(k-1) to determine the increment Po . In addition, the last excitation current decrement L ids is reviewed. On these bases, the decrement step of ids is generated from fuzzy rules through fuzzy inference and defuzzification . It is necessary to process the inputs of FLC-2 in per-unit values[1],[9]. Therefore, the adjustable gains KP and KIDS convert the actual variable to variables with the following expressions:
KP = acar + b

$$KIDS = C_1 \omega_r - C_2 i_{qs} + C_3$$

Where a, b, C1, C2 and C3 are derived from simulation studies.

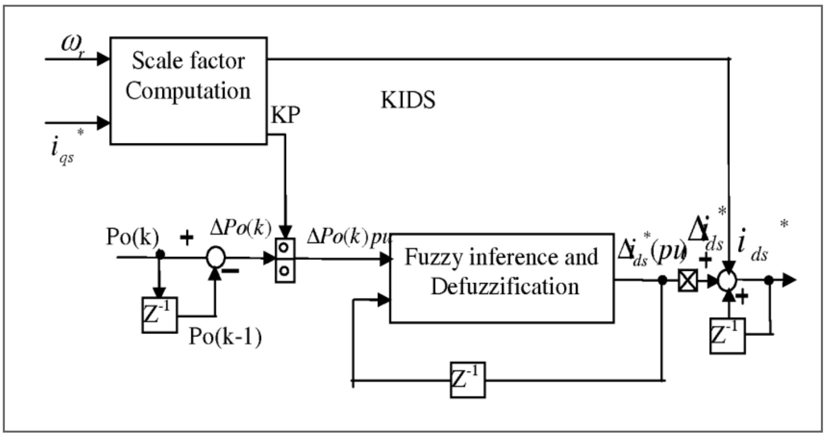

Figure 6: Block Diagram Of FLC-2

$L\Delta i_{ds}^*(pu)$ $\Delta P_o(k)$	N	P
PB	NM	PM
PM	NS	PS
PS	NS	PS
NS	PS	NS
NM	PM	NM
NB	PB	NB

Table 2: Rule Matrix For FLC-2

A typical rule can be read as follows:
"If APo(k) is PM (positive medium) AND LAids* is P (positive) , THEN Aids* is PS (positive small)."

3.3.FLC -3 (Closed Loop Generator Speed Controller)

The block diagram of FLC-3 is given in fig.7.The speed loop error E r* and error change E r* signals are converted to per-unit signals, processed through fuzzy control, and then summed to produce the generator torque component of current iqs* .It has to be noted here that while fuzzy controllers FLC-1 and FLC-2 operate in sequence at steady wind velocity, FLC-3 is always active during system operation.

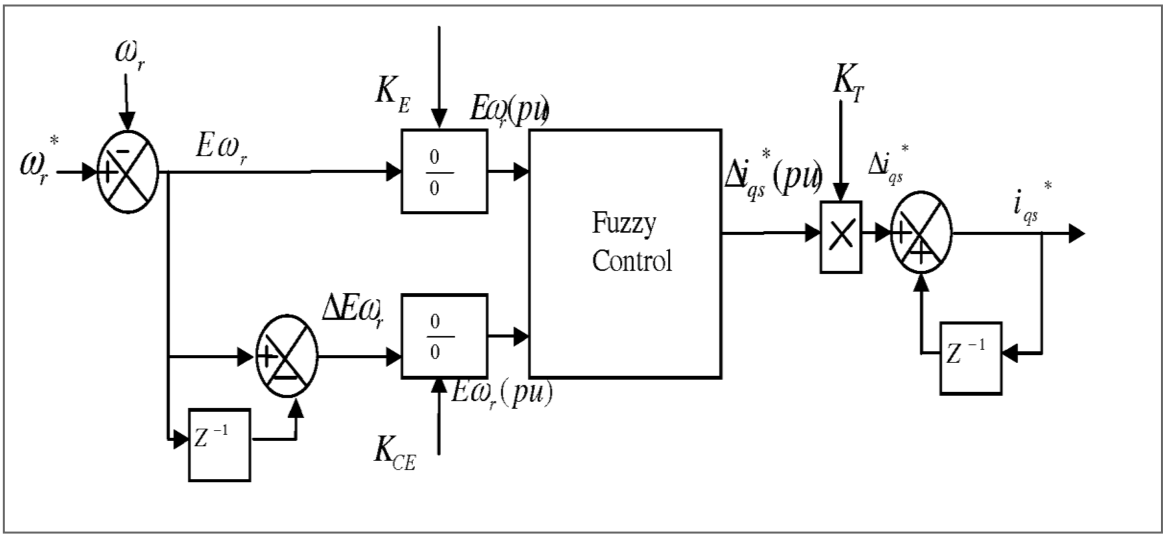

Figure 7: Block Diagram Of FLC-3

$\mathbf{Ew_r(pu)}$ $\mathbf{\Delta Ew_r(pu)}$	**NVL**	**NL**	**NM**	**NS**	**ZE**	**PS**	**PM**	**PL**	**PVL**
NVL					NVL	NL	NM	NS	ZE
NL					NL	NM	NS	ZE	PS
NM				NL	NM	NS	ZE	PS	PM
NS			NL	NM	NS	ZE	PS	PM	PL
ZE		NL	NM	NS	ZE	PS	PM	PL	
PS	NL	NM	NS	ZE	PS	PM	PL		
PM	NM	NS	ZE	PS	PM	PL			
PL	NS	ZE	PS	PM	PL				
PVL	ZE	PS	PM	PL	PVL				

Table 3: Rule Matrix For FLC-3

4.Simulation Circuits

4.1.Squirrel Cage Induction Machine Parameters

Three phase, Y-connected	
Power rating	=10 hp
Voltage rating	=460v
Current rating	=7.6A
No. of poles	=4
Speed	=1760 rpm
Stator resistance (Rs)	=0.68377 ohm
Rotor resistance (Rr)	=0.451 ohm
Stator leakage inductance (Lls)	=4.152 mH
Rotor leakage inductance (Llr)	=4.152 mH
Magnetizing inductance (Lm)	=148.6 mH

Table : 4

4.2.Turbine Parameters

Output power	= 3.5KW
Tower	= 99.95m
Speed	= 11.1-22.2 r.p.m.
η_{GEAR}	= 5.2.

Table: 5

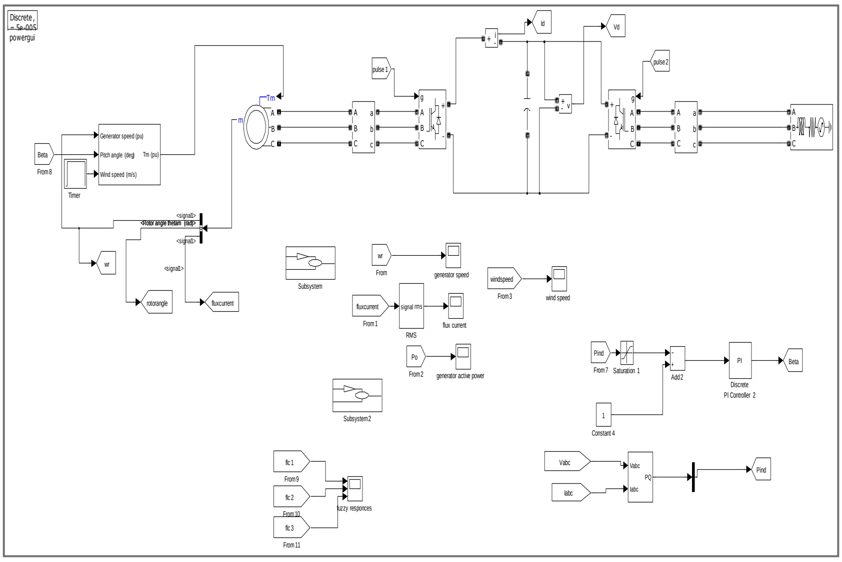

Figure 8: Simulink Model Of The Control System Block Diagram With Fuzzy Logic Controller

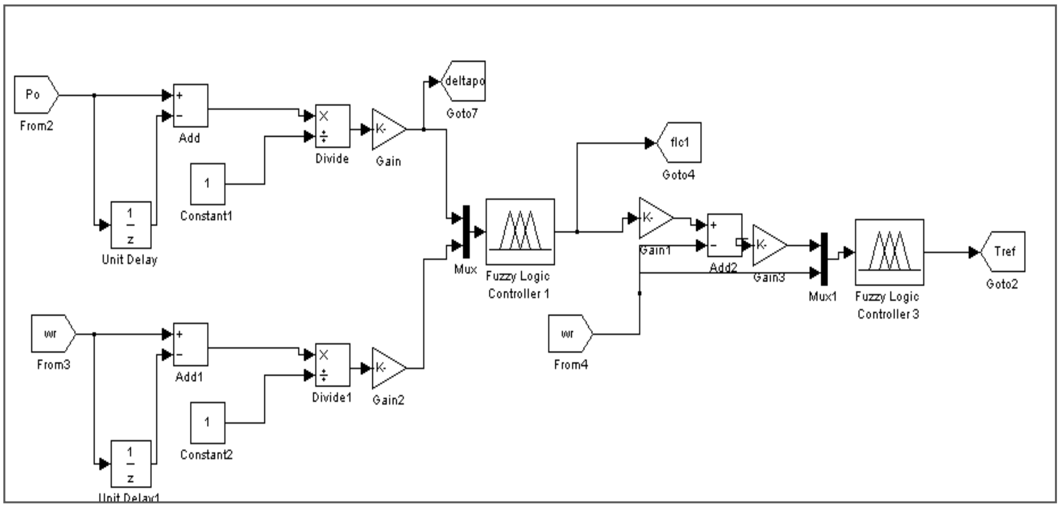

Figure 9: Study System To Generate Tref

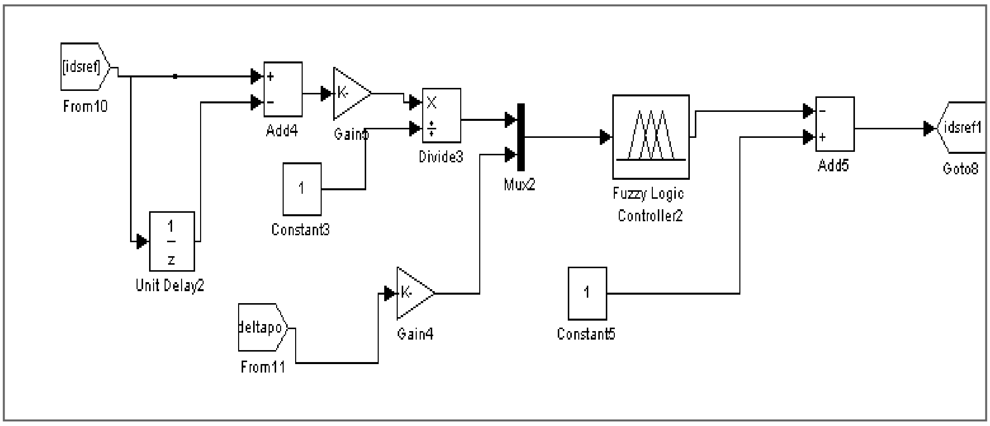

Figure 10: Study System To Generate Idsref1

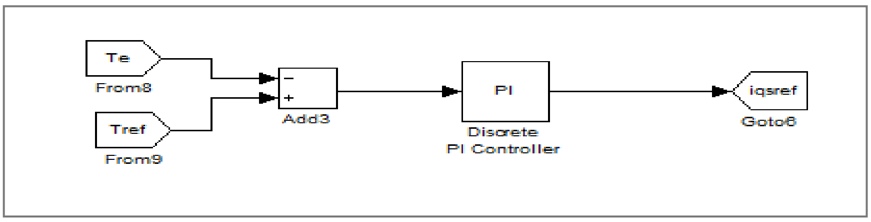

Figure 11: Study System To Generate Iqsref

5.Simulation Results

The wind velocity has been taken as the input for obtaining closed loop response of the wind generation system. With respect to the change in the wind velocity, the outputs are observed .Here the turbine is modeled with aerodynamic torque(Tm) and turbine oscillatory torque (TOSC) and some turbulence has also been added with the wind velocity to verify the robustness of FLC-3. FLC-1 will track the generator speed with the change in wind velocity to extract maximum power. So as the wind velocity increases, generator speed is also increased by FLC-1 by observing the generator speed waveform with using fuzzy logic controllers.

As a result of which the corresponding line output power is also increased during the interval FLC-1 is active by assuming a lossless system. Similar is the case for the decrease in wind velocity. FLC-2 will reduce the generator rotor flux for light load efficiency improvement.FLC-2 reduces the flux component of current i.e. i_{ds}. Thus core loss of machine decreases but on the other hand torque component of current iqs is increased, which in turn increases the copper loss of the machine.

5.1.With Using Fuzzy Logic Controllers

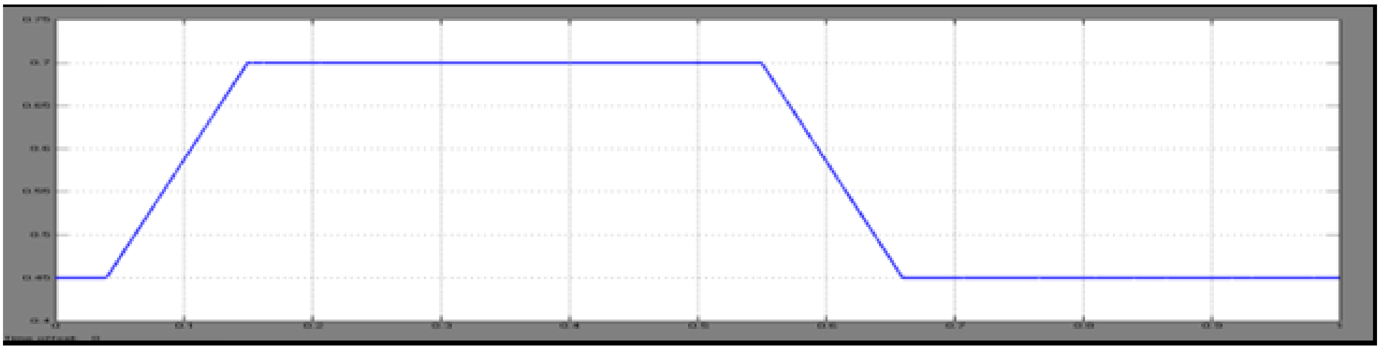

Figure 12: Wind Velocity

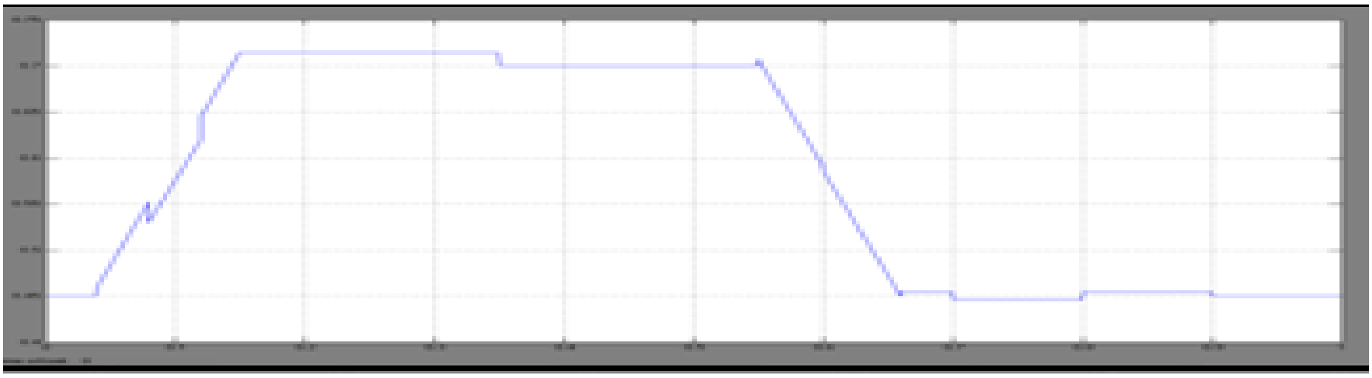

Figure 13: Generator Speed

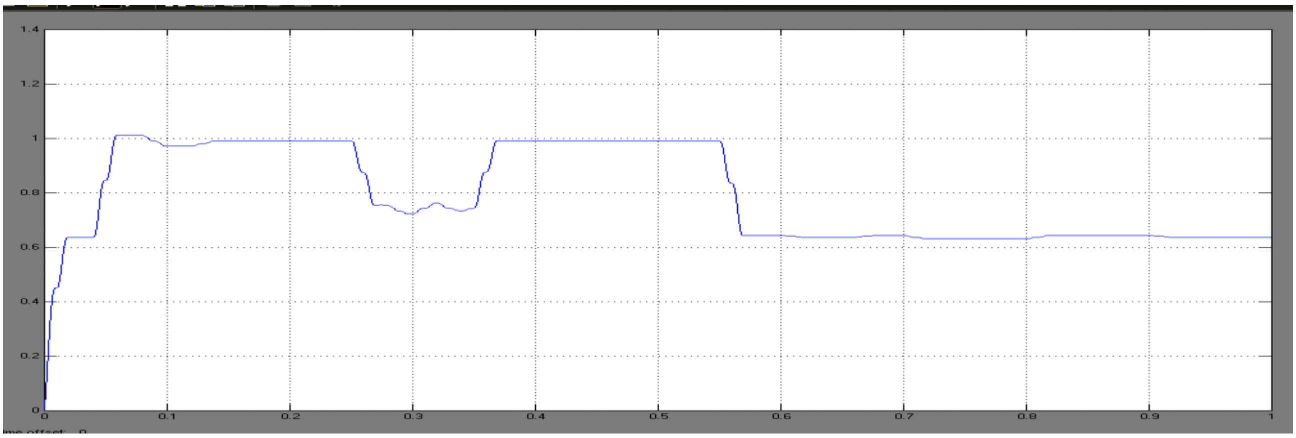

Figure 14: Flux Current

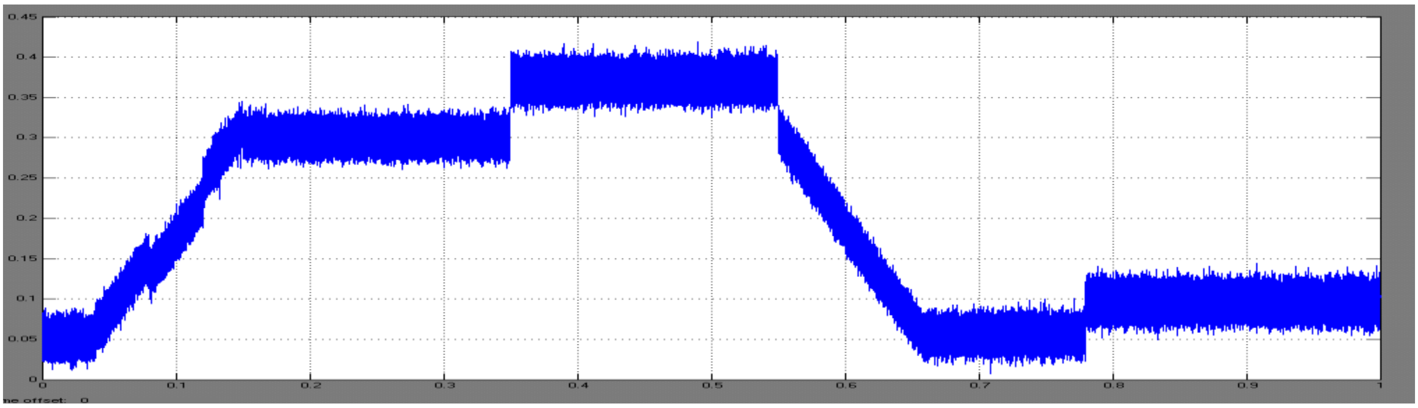

Figure 15: Output Power

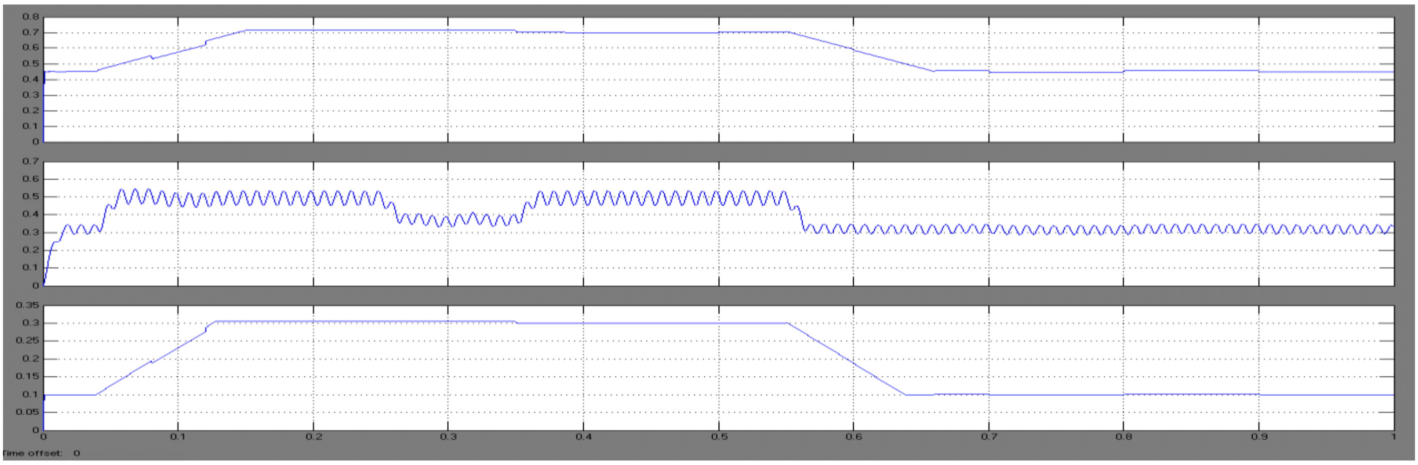

Figure 16: Fuzzy Output

5.2.With Out Using Fuzzy Logic Controllers

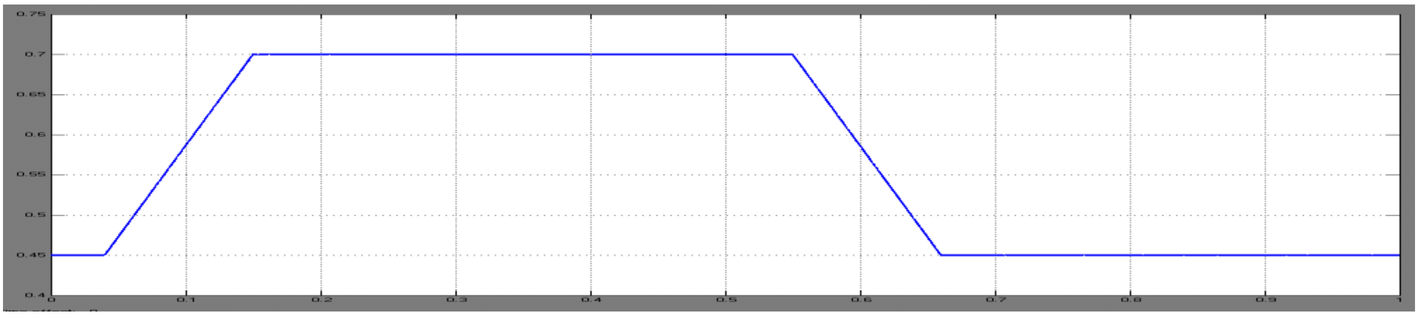

Figure 17: Wind Velocity

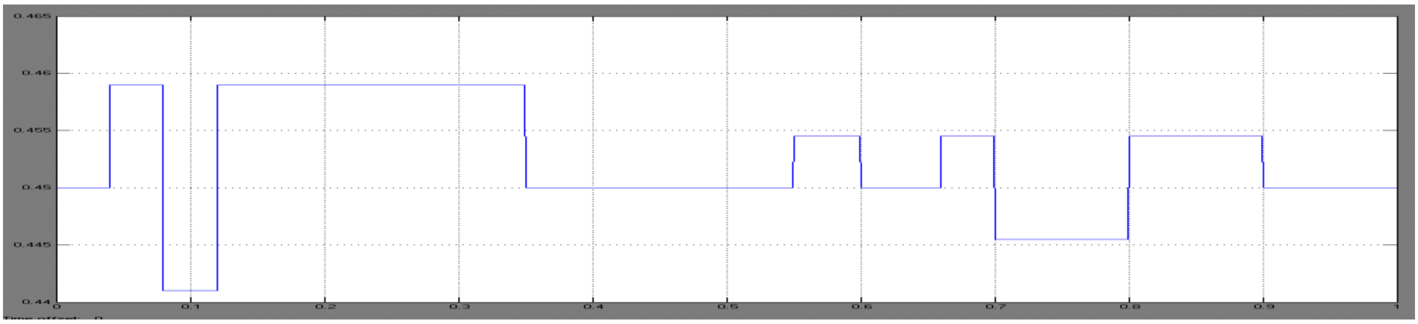

Figure 18: Generator Speed

Figure 19:Flux Current

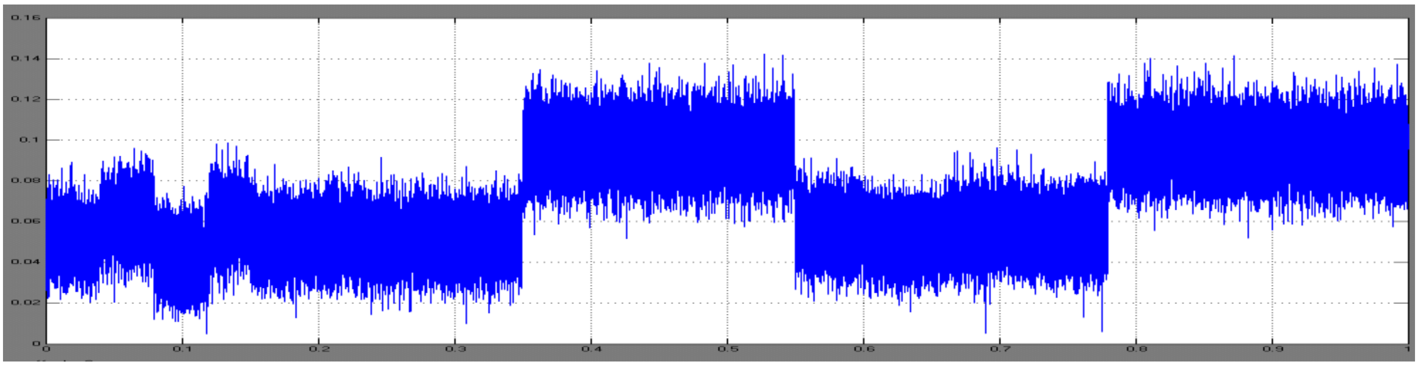

Figure 20: Output Power

6.Conclusion

In wind generation system the squirrel cage machine speed performances has been analyzed with fuzzy logic controller and the variable speed performances have been studied with MATLAB –Simulink tool, and also we have done the speed performance analysis of induction machine in wind generation system without fuzzy controller. In this paper we have done the comparison of both speed performances of induction machine with and without fuzzy controller. By these comparisons we have observed that without using fuzzy controller the system is insensitive but when we are applied the fuzzy controller to the speed variations, the system performance is excellent. so we got the clarification regarding with and without using fuzzy logic controller for the induction machine speed variations in wind generation system.

7. References

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