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Comparison of PI and FUZZY Logic Controller Based STATCOM in Wind Turbine Fed FSIG under Asymmetric Faults

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Abstract

This paper presents detailed analysis to compare the performance of wind turbine under assymmetric faults using static compensator with PI and Fuzzy logic controller. A static compensator control structure is used to compensate the positive and negative sequence voltage compensation under different fault conditions as the negative sequence voltage causes heavy torque oscillations that reduces the life of the drive train. The direct quadrature axis theory is the vector control method used in static compensator. This method aims to compensate positive and negative sequence voltages. Simulations have been carried out with PI controller and fuzzy logic controller based STATCOM in Matlab/Simulink. comparative analysis has been carried out for the direct quadrature control strategy of different assymmetric faults and analyze the direct and quadrature axis of current and voltage, torque, speed, active and reactive power. The fuzzy logic controller gives better performance than PI under asymmetric faults and suppresses the torsional oscillations thereby improving the overall performance of the system.

Keywords: Fixed Speed Induction Generator, Wind Turbine, Fuzzy Logic Controller, Static compensator.

Introduction

The wind power penetration has increased dramatically in the past few years, hence it has become necessary to address problems associated with maintaining a stable electric power system that contains different sources of energy including hydro, thermal, coal, nuclear, wind, and solar. In the past, the total installed wind power capacity was a small fraction of the power system and continuous connection of the wind farm to the grid was not a major concern. With an increasing share derived from wind power sources, continuous connection of wind farms to the system has played an increasing role in enabling uninterrupted power supply to the load, even in the case of minor disturbances. The wind farm capacity is being continuously increased through the installation of more and larger wind turbines[1]. Voltage stability and an efficient fault ride through capability are the basic requirements for higher penetration. Wind turbines have to be able to continue uninterrupted operation under transient voltage conditions to be in accordance with the grid codes. Grid codes are certain standards set by regulating agencies. Wind power systems should meet these requirements for interconnection to the grid. Different grid code standards are established by different regulating bodies [2] but Nordic grid codes are becoming increasingly popular. One of the major issues concerning a wind farm interconnection to a power grid concerns its dynamic stability on the power system. Voltage instability problems occur in a power system that is not able to meet the reactive power demand during faults and heavy loading conditions. Stand alone systems are easier to model, analyze, and control than large power systems in simulation studies. A wind farm is usually spread over a wide area and has many wind generators, which produce different amounts of power as they are exposed to different wind patterns. but the fixed speed induction generators have a poor reactive power capability when compared to doubly fed induction generator[3]. Alhough different types of FACTS controllers are available, UPQC and STATCOM have a good fault mitigation capability.

Wind Turbine Fixed Speed Induction Generator

A. Grid Connected Induction Generator

Grid connected induction generators develop their excitation from the Utility grid. The generated power is fed to the supply system when the IG is run above synchronous speed. Machines with

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cage type rotor feed only through the stator and generally operate at low negative slip. But wound rotor machines can feed power through the stator as well as rotor to the bus over a wide range known as Doubly Fed Induction Machines[4].

B. Fixed Speed Grid Connected Wind Turbine Generator

The structure and performance of fixed-speed wind turbines as shown in Fig..1 depends on the features of mechanical sub-circuits, e.g., pitch control time constants etc.

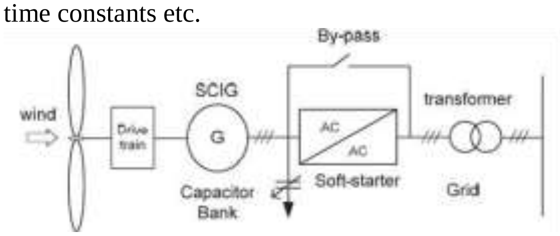

Fig : 1 Fixed Speed Wind Turbine With Directly Grid Connected Squirrel - Cage Induction Generator

The reaction time of these mechanical circuits may lie in the range of tens of milliseconds. As a result, each time a burst of wind hits the turbine, a rapid variation of electrical output power can be observed[3]. These variations in electric power generated not only require a firm power grid to enable stable operation, but also require a well-built mechanical design to absorb high mechanical stress, which leads to expensive mechanical structure, especially at high-rated power[7].

Static Compensator (Statcom)

The basic electronic block of the STATCOM is the voltage source inverter[5] that converts an input dc voltage into a three-phase ac output voltage at fundamental frequency. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the STATCOM output voltages allow effective control of active and reactive power exchanges between the STATCOM and the ac system. The first transformer is in Y-Yconnection and the second transformer is in Y- connection. The first transformer is step down and the second one is step up transformer. The IGBT of the proposed STATCOM is inturn fed to dq reference frame and DSOGI-PLL which is used to separate the positive sequence and negative sequence voltages and currents[8].

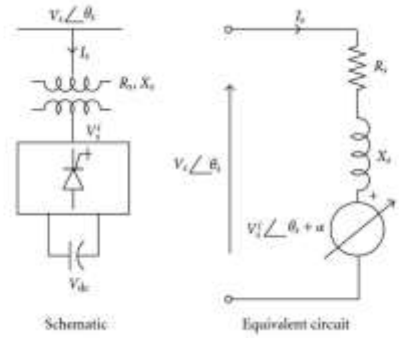

Fig:2: STATCOM structure

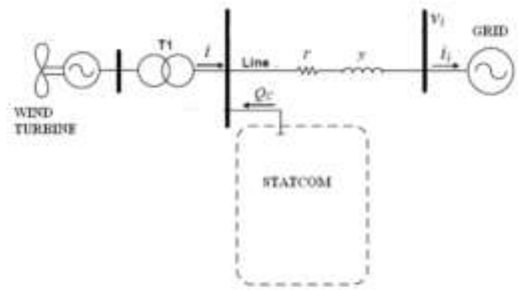

Fig: 3 : System Model

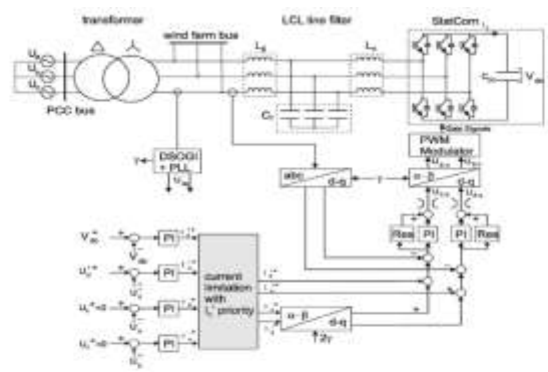

Fig:4: STATCOM Control Structure

Fuzzy Logic Controller

The control system is based on fuzzy logic. This type of control, approaching the human reasoning that makes use of the tolerance, uncertainty, imprecision and fuzziness in the decision-making process, manages to offer a very satisfactory performance, without the need of a detailed mathematical model of the system, just by incorporating the experts knowledge into fuzzy[4].The fuzzy logic control system is based on mamdani fuzzy model. This system consist four main components. First, using input membership functions, inputs are fuzzified then based on rule bases and inference system, outputs are produced and finally the fuzzy outputs are defuzzified and applied to the

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main control system. Error of inputs from their references and error deviations in any time interval are chosen as inputs[6]. These parts are simulated in MATLAB. The output of fuzzy controller is the value that should be added to the prior output to produce new reference output.

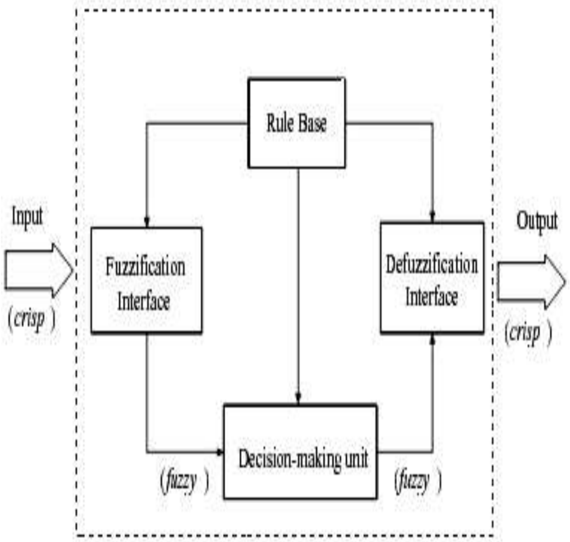
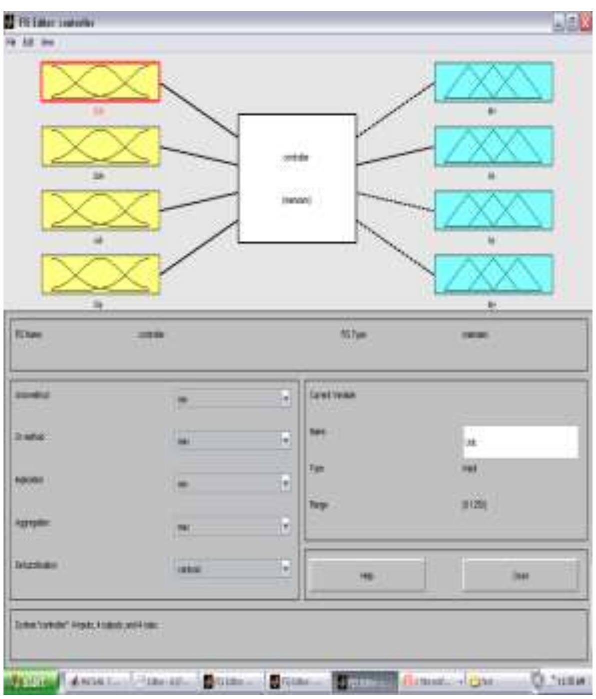
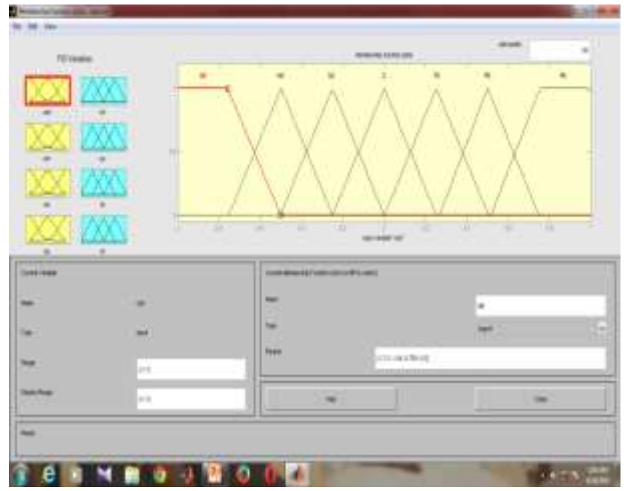


Fig:5 : Block Diagram of fuzzy logic controller

STEP1: SELECTION OF INPUT AND OUTPUT VARIABLES



STEP2: ASSIGNING MEMBERSHIP FUNCTIONS



STEP3: RULE TABLE

e / Δe	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NB	NM	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NB	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PS	PB	PB	PB	PB

STEP4: DEFUZZIFICATION

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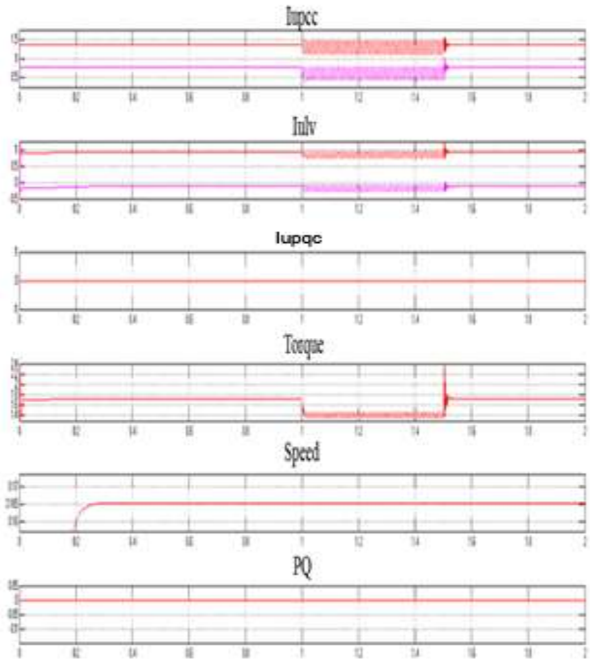
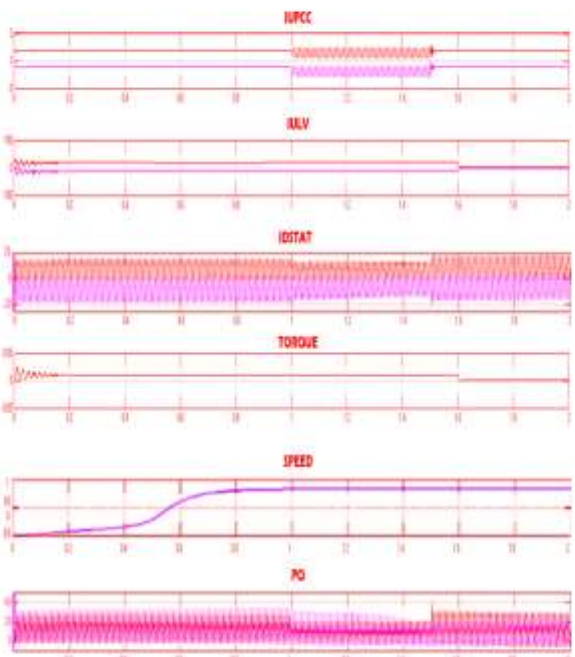
Simulation Results

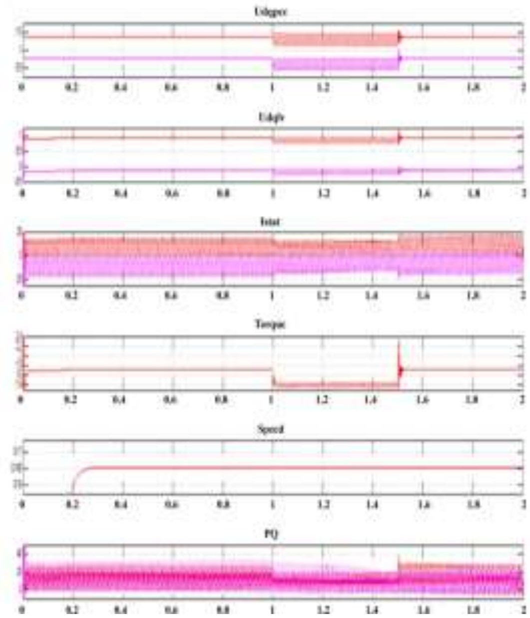
A. Wind Turbine Fed Fsig Without STATCOM



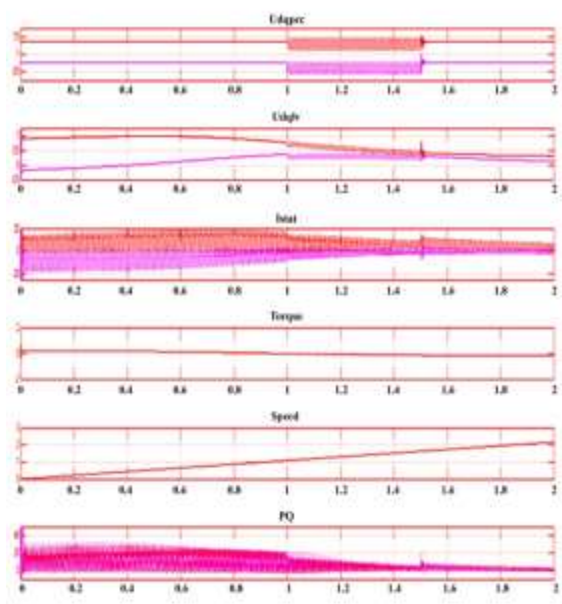
B. Wind Turbine Fed Fsig With STATCOM



C. With STATCOM -1ph-50%- Positive Sequence Compensation Vector Control-PI



D. With STATCOM -1ph-50%- Positive Sequence Compensation Vector Control-Fuzzy



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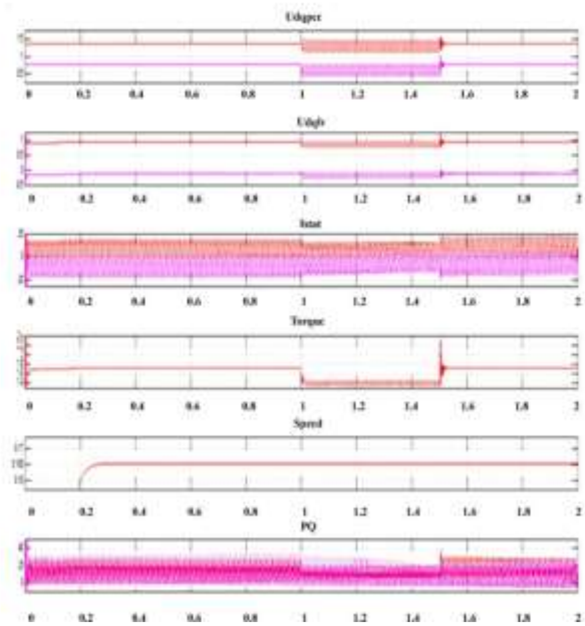
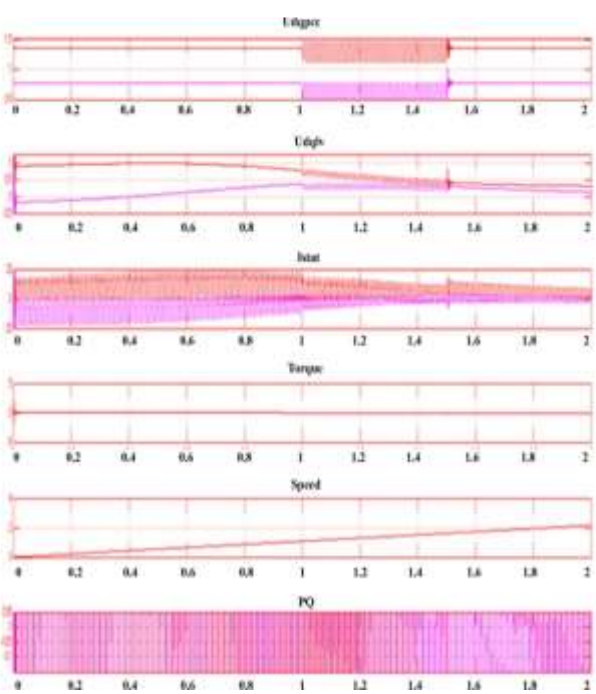
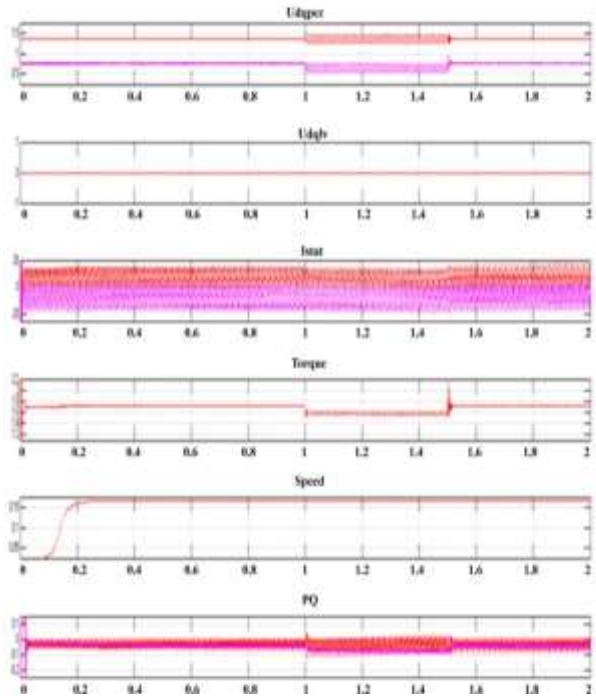
E. With STATCOM -1ph-50%-Negative Sequence Compensation Vector Control- PI



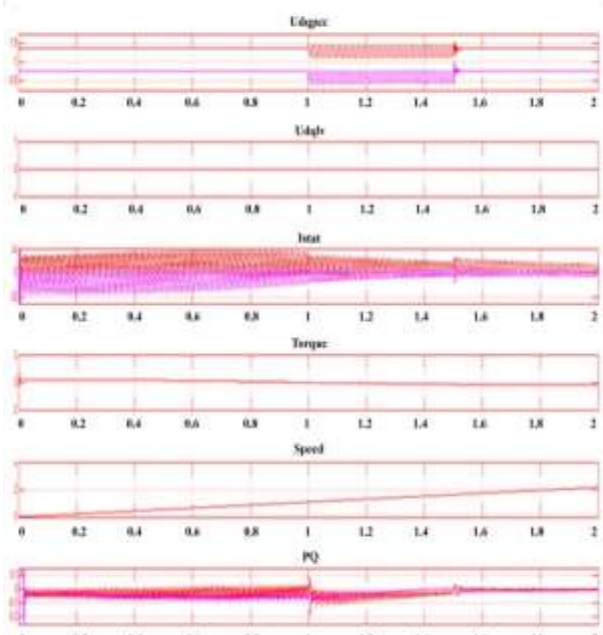
F. With STATCOM -1ph-50%-Negative Sequence Compensation Vector Control- FUZZY



G. With STATCOM -1ph 60%- Co Ordinated Positive & Negative Sequence Compensation Vector Control- PI



H. With STATCOM -1ph 60%- Co Ordinated Positive & Negative Sequence Compensation Vector Control- FUZZY



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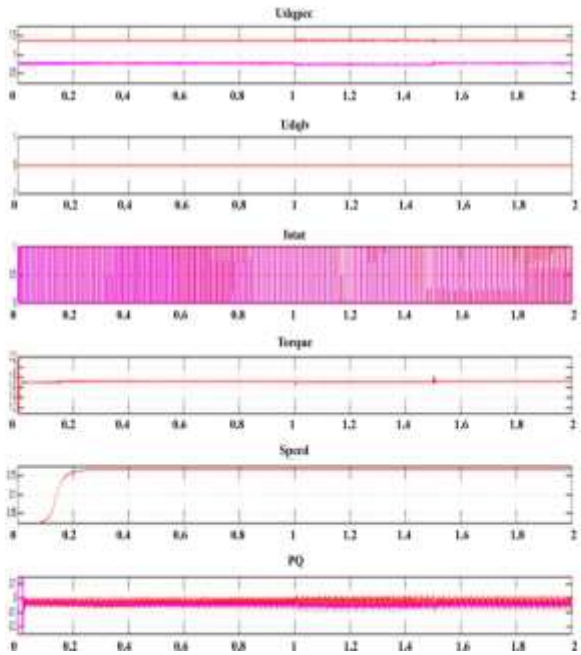
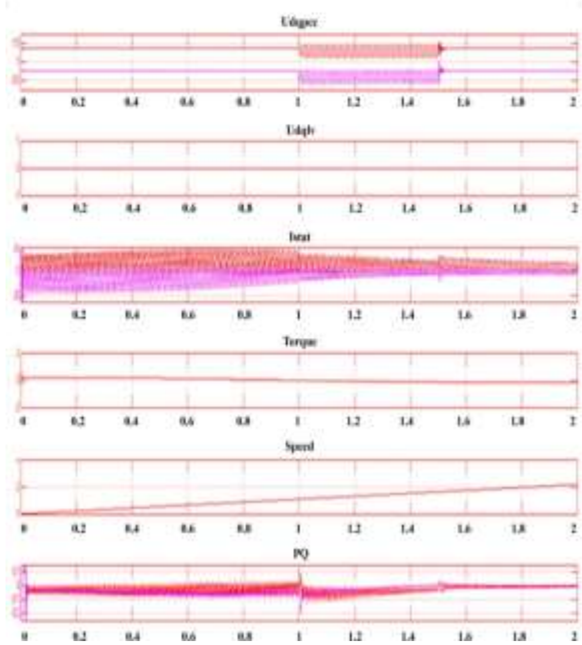
I. *With STATCOM -1ph 0%- Co-Ordinated Positive & Negative Sequence Compensation Vector Control- PI*



J. *With STATCOM -1ph 0%- Co-Ordinated Positive & Negative Sequence Compensation Vector Control- FUZZY*



Tabulation

1. ***1ph-50% FAULT POSITIVE SEQUENCE COMPENSATION***

SL.NO	PARAMETERS	SETTLING TIME(seconds)		PEAK OVERSHOOT(%)	
		Vector Control		Vector Control	
		PI	FUZZY	PI	FUZZY
1	Iudqpcc	5.2213	5.1878	41.4%	34.2%
2	Iulv	5.2293	5.2277	83.2%	70.7%
3	Istat	5.2199	5.2216	68.5%	43.5%
4	Torque	5.2256	5.2230	71.5%	41.4%
5	Speed	5.2232	5.2210	83.99%	66.5%
6	P.Q	5.2213	5.1878	59.8%	25.7%

2. ***1ph-50% FAULT NEGATIVE SEQUENCE COMPENSATION***

S.N	PARAMETERS	SETTLING TIME		PEAK OVERSHOOT	
		Vector Control		Vector Control	
		PI	FUZZY	PI	FUZZY
1	Iudqpcc	5.2295	5.2231	43.3%	31.8%
2	Iulv	5.2237	5.2214	85.4%	72.2%
3	Istat	5.2199	5.2216	64.66%	33.67%
4	Torque	5.2254	5.2210	73.2%	40.8%
5	Speed	5.2232	5.2215	82.17%	65.5%
6	P.Q	5.2295	5.2249	56.42%	22.3%

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3. 1ph-60% FAULT POSITIVE AND NEGATIVE SEQUENCE COMPENSATION

S. N	PARAMETERS	SETTLING TIME		PEAK OVERSHOOT	
		Vector Control		Vector Control	
		PI	FUZZY	PI	FUZZY
1	Iudqpcc	5.2273	5.2219	75.7%	60.7%
2	Iulv	5.2236	5.2166	60.9%	48.2%
3	Istat	5.2244	5.2218	54.27 %	36.55 %
4	Torque	5.2253	5.2230	79.80 %	44.66 %
5	Speed	5.2197	5.2144	81.3%	47.1%
6	P.Q	5.2248	5.2216	45.95 %	14.14 %

4. 1ph-0% FAULT POSITIVE AND NEGATIVE SEQUENCE COMPENSATION

SL.NO	PARAMETERS	SETTLING TIME		PEAK OVERSHOOT	
		Vector Control		Vector Control	
		PI	FUZZY	PI	FUZZY
1	Iudqpcc	5.2266	5.2225	84.6%	73.3%
2	Iulv	5.2242	5.2212	67.2%	45.9%
3	Istat	5.2258	5.2237	58.1%	25.4%
4	Torque	5.2249	5.2215	77.5%	32.12%
5	Speed	5.2132	5.2120	82.44%	55.6%
6	P.Q	5.2239	5.2210	46.33%	19.74%

Conclusion

The fuzzy logic controller is implemented and compared with PI fed vector control for wind turbine fed FSIG under different assymmetric faults using STATCOM. It is observed that the settling time and peak overshoot is reduced considerably in fuzzy logic based controller. Hence Fuzzy logic controller surpass the traditional PI control during non linear variations and it gives better performance than PI in wind turbine fed FSIG under different assymetric faults.

A. Appendix

TABLE I. Simulation Parameters

Wind Farm Induction Generator	Simulation Parameters
Base Apparent Power	575 MW
Rated Active Power	50 MW
Rated Voltage (Line To Line)	690 V
Stator Resistance	0.0108 p.u
Stator Stray Impedance	0.107 p.u
Mutual Impedance	4.4 p.u
Rotor Impedance	0.01214 p.u
Rotor Stray Impedance	0.1407 p.u
Compensation Capacitors	0.17 F
Mechanical Time Constant	3s

B. Grid And Transformer Parameters

	Grid	High Voltage Transformer	Medium Voltage Transformer
Base Apparent Power and Rated Voltage	1000 MW 110 KV	100 MW 30 KV	100 MW 690 V
Stray Impedance	0.98 p.u	0.05 p.u	0.1 p.u
Resistance	0.02 p.u	0.01 p.u	0.02 p.u

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