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Modeling of FUZZY Controlled UPFC for LVRT Improvement in DFIG Based Grid Connected Wind Farm

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Abstract

At present, wind energy generation, usage and its grid infusion is extended in and around the globe. In any case, wind generation is fluctuating a result of time changing nature and causes reliability issues. Wind control fluctuation and network stack changes make disrupting impacts in the PCC voltage. Moreover, Factor speed wind turbine generators foundation has been basically extended worldwide over the latest couple of years. Regardless, issues at the cross section side may require the partition of the wind turbine from the network under such events. Wind Turbine Generator (WTG) may not fit in with the progressing made cross section codes for Wind Energy Change Frameworks (WECS). Doubly Bolstered Enlistment Generator (DFIG) is considered for the variable speed wind farms. The joining of wind turbine into the network makes number of power quality issues. The proposed network generation Low Voltage Ride Through (LVRT) limit of DFIG and it is enhanced by techniques for using Actualities gadgets. Certain devices are used to control the power stream, to extend as far as possible and to enhance the security of the power matrix. A champion among the most comprehensively used Realities contraption is Brought together Power Stream Controller (UPFC). It contains shunt and plan controllers which are related with a DC interface capacitor. By and by methodology for UPFC to improve the LVRT capacity of a DFIG-based breeze ranch voltage list by using Fuzzy Logic Controller (FLC) has been talked about. Thusly the UPFC can satisfactorily improve the LVRT limit of DFIG-based breeze develop, keeping up the breeze turbine to be related with the network amid blame condition. Recreation is finished by using MATLAB/Simulink Instrument.

Keywords: *DFIG, LVRT, UPFC, FUZZY System, Voltage Stability*

INTRODUCTION

With the expansion in populace and industrialization, the vitality request has been expanded fundamentally. Presently multi day, the sustainable power sources have ending up mainstream when contrasted with other regular vitality sources [1]. Wind energy is the most best sustainable power source for the generation of electric power [2]. At first the settled speed wind turbines were utilized for the generation of intensity, however at this point multi day the variable speed wind turbines has turned out to be prominent in light of its focal points over settled speed wind turbines [3]. These variable speed wind turbines are capable enhance the wind vitality generation, out of all factor speed wind turbines, DFIG has been utilized generally on account of its ease, higher vitality yield, and autonomous control of genuine and receptive power [4], [5]. Anyway the DFIG wind turbines are confronting the issues of intensity vacillation amid typical activity in the framework and this prompts low voltage ride through [LVRT] amid the blame event [6]. At the underlying stages, WTG'S are permitted to disengage from the network amid blame. Be that as it may, because of expanding pattern in WTG'S, it is fundamental for the wind turbine to be associated with the lattice, notwithstanding when blame happens in the framework [6], [7]. As indicated by the lattice code prerequisites the wind homesteads ought to add to control framework control like recurrence and voltage and make the wind turbine to be associated with matrix and bolster it by infusing the receptive capacity to the network [8]. This low voltage ride through [LVRT] ability has been enhanced by utilizing a functioning crowbar insurance plot in the framework, however the embodiment of this plan is just to control the rotor twisting as it were. For better execution actualities gadgets can be utilized.

UNIFIED POWER FLOW CONTROLLER

A Unified power stream controller [UPFC] is a FACTS gadget which is for the most part used to control and to advance the power stream in electrical power transmission frameworks. UPFC is fundamentally a blend of a Static compensator (STATCOM) and Static Synchronous Series Compensator (SSSC) coupled through a typical dc connect.

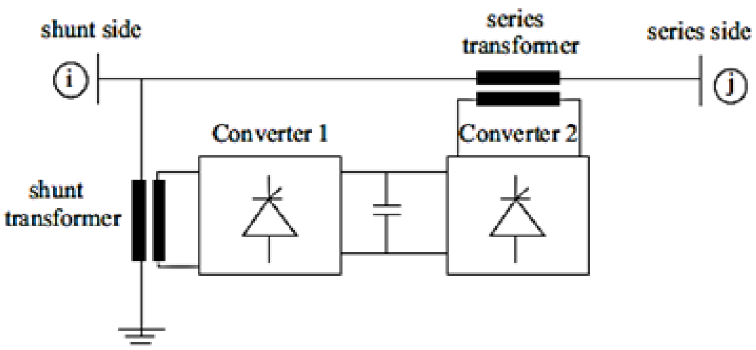

Figure 1: *Block diagram of Back to Back Converter with UPFC*

Both the shunt and series converters are associated through series and shunt transformers individually. The shunt inverter and seriesconverters of the UPFC can control both dynamic and responsive intensity of the framework at the PCC easily.

MODELING OF UPFC

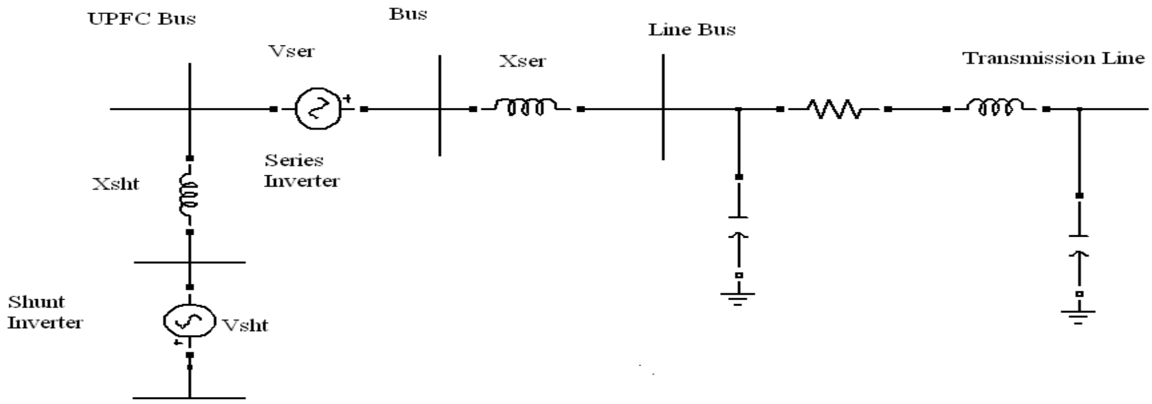

Figure 2: *One line digram of UPFC system*

X_{sht} – reactance of transformers T_1
X_{ser} – reactance of transformers T_2
V_{sht} and V_{ser} - Voltage generated by the shunt and series inverter
Bus A and B – UPFC bus and transmission line side bus of UPFC
The shunt and series voltage sources can be mathematically represented as

$V_{sht} = V_{sht}[\cos\theta_{sht} + j\sin\theta_{sht}]$ (1)
$V_{ser} = V_{ser}[\cos\Psi_{ser} + j\sin\Psi_{ser}]$ (2)
Where,
V_{sht} – and V_{ser} are root mean squared magnitudes of shunt and series voltage sources

Q_{sht} & Ψ_{ser} – Shunt and series voltage sources angles

The real and reactive power injections at bus A is,
$P_A = - V_{ser} Y_{AB} V_A \cos[\theta_A - \Psi_{ser} - \Phi_{AB}]$ (3)
$Q_A = -V_{ser} Y_{AB} V_A \sin[\theta_A - \Psi_{ser} - \Phi_{AB}]$ (4)
At the bus B the real and reactive power injections are
$P_B = - V_{ser} Y_{AB} V_B \cos[\theta_B - \Psi_{ser} - \Phi_{AB}]$ (5)
$Q_B = - V_{ser} Y_{AB} V_B \sin[\theta_B - \Psi_{ser} - \Phi_{AB}]$ (6)

Where,
Y_{AB} – admittance between the bus A and bus B
Φ_{AB} – Phase angle
For constancy of DC link capacitor voltage the following relation should be satisfied
$P_{sht} + P_{ser} + P_{loss} = 0$ (7)
Where,
P_{sht} and P_{ser} – real powers exchanged with power system by shunt and series voltage sources
P_{loss} – losses in UPFC
The real power demand P_{sht} by the shunt voltage source is given by
$P_{sht} = -V_{ser} V_k Y_{km} \cos[\Psi_{ser} - \theta_k - \Phi_{km}] + V_{ser} V_m V_{ykm} \cos [\Psi_{ser} - \theta_k - \Phi_{km}] - (V_{dc}^2)/R_{capa}$ (8)

Where,
V_{dc} – DC link capacitor voltage
Therefore equations shown in above are used to perform load flow studies for obtaining a steady state power flow conditions.

PRINCIPLE OF DFIG AND ITS OPERATION

The Figure.3 demonstrates the framework under examination, it comprises of a two 1.5MW DFIG's that are coupled to the transmission line at the Point of Common Coupling [PCC]. The DFIG is an acceptance machine with an injury rotor, where both the stator and rotor are associated with electrical sources. The stator is straightforwardly associated with network and rotor is associated with slip rings through three stage converters. The converters are Grid side converter (GSC) and Rotor Side Converters (RSC) which are associated consecutive and there is a DC interface capacitor set between two converters. The GSC is associated with the framework through a transformer and the breeze turbines are associated by means of 30km transmission line. Under typical working conditions the responsive power created by the DFIG is controlled at zero MVar all together keep up solidarity control factor. To enhance the execution of the DFIG and furthermore to direct the voltage UPFC is associated at PCC.

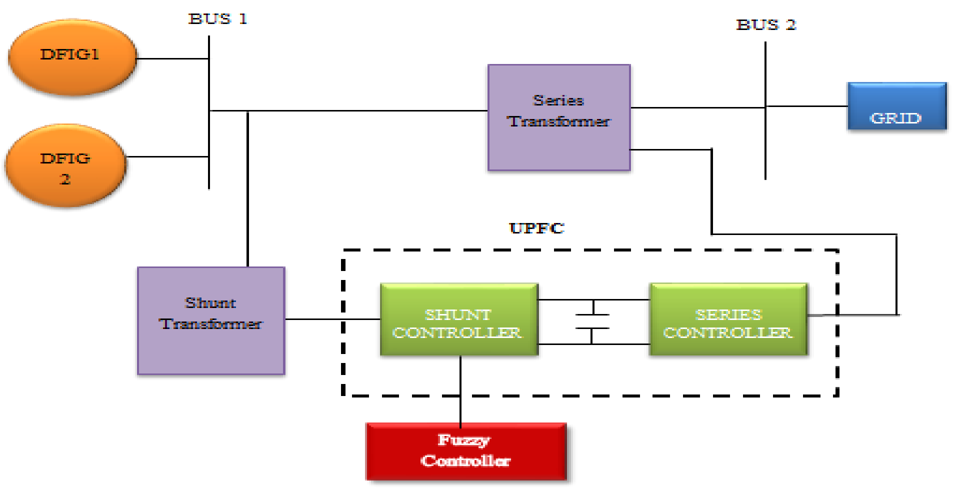

***Figure 3:** Block diagram of the system with UPFC*

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MODELING OF UPFC WITH FUZZY SYSTEM

This segment checks the exactness and unwavering quality of the proposed plan through recreation and correlation of the execution with a few surely understood plans. The shunt and arrangement converters of the UPFC are controlled utilizing Proportional Integral (PI) and Fuzzy Logic Controller (FLC) individually.

Design of Series Controller

The series inverter is used to control the real and reactive line power flow by inserting a voltage of controllable magnitude and phase in series with the transmission line.

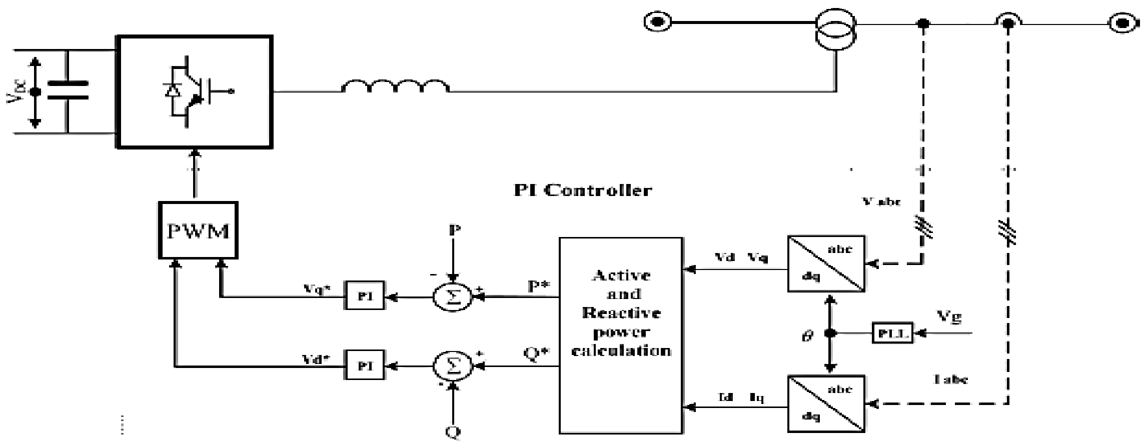

Figure 4: *Series Converter configuration and the proposed PI control scheme*

As appeared in Figure.4 the contrasts between the generator dynamic and receptive forces and their pre-set qualities are utilized as info signs to the PI controllers which are tuned to produce the reference voltage esteems in d-q reference outline (Vd* andVq*) required for controlling converter switches utilizing Pulse Width Modulation (PWM).

Design of Shunt Controller

Fuzzy Logic is one of the effective uses of Fuzzy set in which the factors are semantic as opposed to the numeric factors. Fuzzy Logic controller is intended to limit variance on framework yields. The Figure.5 demonstrates the fundamental design of Fuzzy Logic Controller with its different working units. Each of the standards characterizes one participation which is the capacity of FLC. The contributions to the Fuzzy Logic controller are Angle and the yield is the Error esteem. The info participation capacities are structured utilizing triangular formed part works (tri). The single yield of the FLC is meant by delU and the yield part work is structured by triangular formed part work (tri).

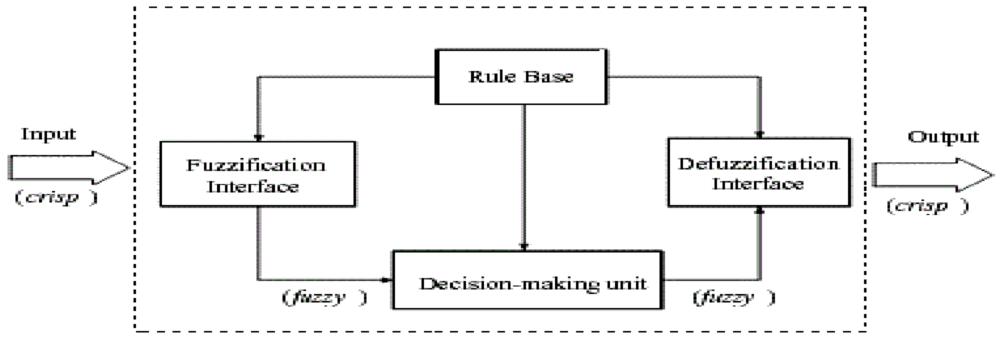

Figure 5: *Basic configuration Fuzzy Logic Controller*

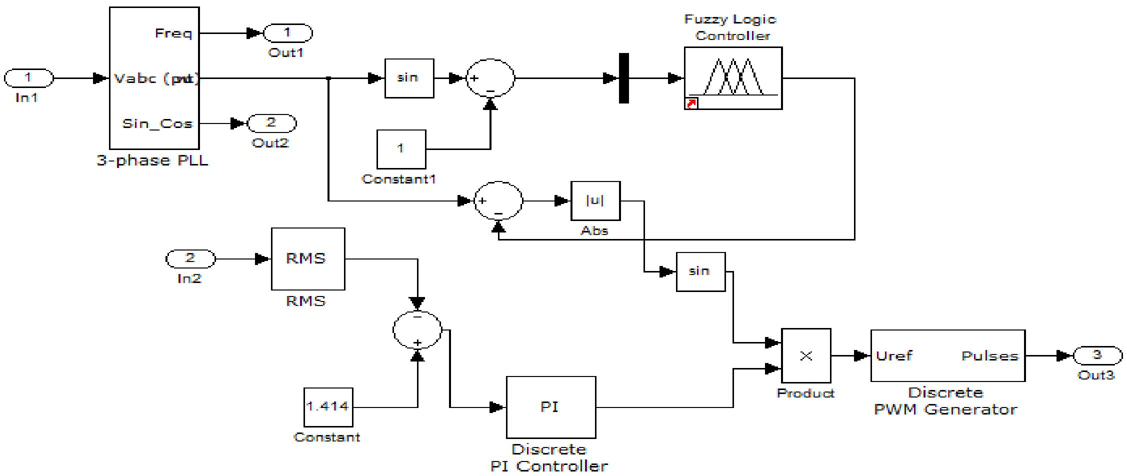

***Figure 6:** Shunt controller with Fuzzy Logic Control*

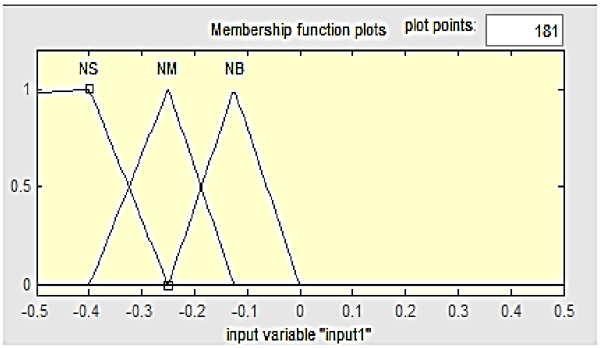

***Figure 7(a):** Input membership functions*

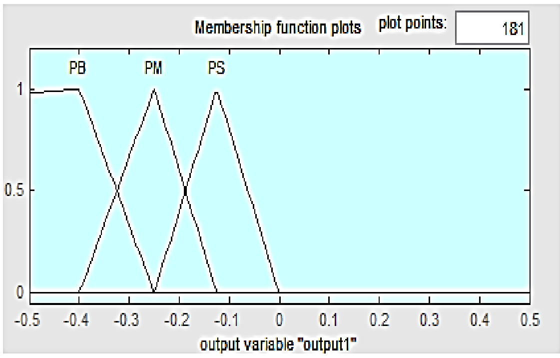

***Figure 7(b):** Output membership functions*

The blunder (distinction between the reference esteem and estimated framework parameters) and the rate of progress of mistake are the contributions for Mamdani fuzzy framework. The yield from the surmising framework is given to PWM generator to deliver required changing heartbeats to UPFC.

The Table.1 demonstrates the information and yield participation capacities for the shunt controller of UPFC.In a control framework, mistake among reference and yield can be named as, Positive Small (PS), Negative Small (NS), Positive Medium (PM), Negative Medium (NM), Positive Big (PB), Negative Big (NB). The way toward changing over a numerical variable (genuine number) convert to a phonetic variable (fuzzy number) is called fuzzification.

INPUT	OUTPUT
NB	PS
NM	PM
NS	PB

Simulation Results

Simulation results are done to dissect the execution of DFIG based breeze ranch utilizing UPFC for voltage sag conditions in a transmission framework. Here we consider a Transmission framework with a voltage of 440V and 50Hz. A three stage blame with blame opposition of 0.0023ω is said to be brought into the framework. The voltage hang is brought into the framework for a time of 0.1 to 0.2s. The voltage list is said to be remunerated in the transmission line utilizing UPFC with PI controller and Fuzzy Logic controller.

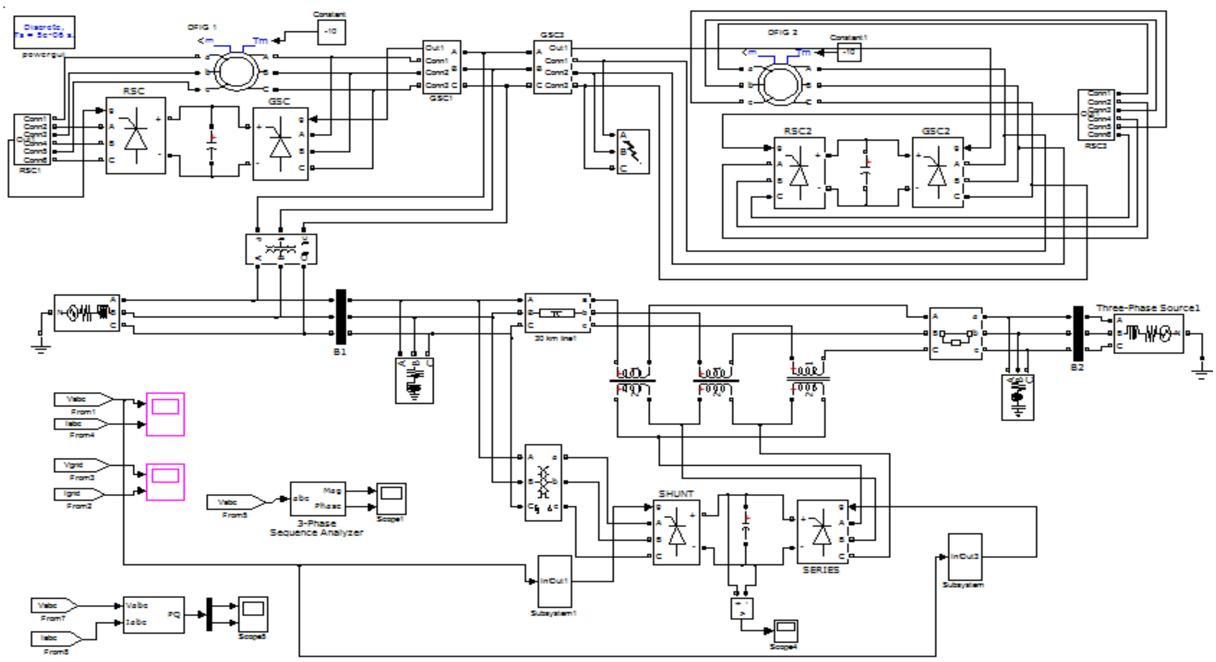

***Figure 8:** Overall simulation diagram of DFIG with UPFC*

Response of the System without UPFC

The simulation result for the proposed UPFC system with DFIG is shown in below Figures. 9 (a) - 9(c) shows when the system undergoes a fault at 0.1s to 0.2 s.

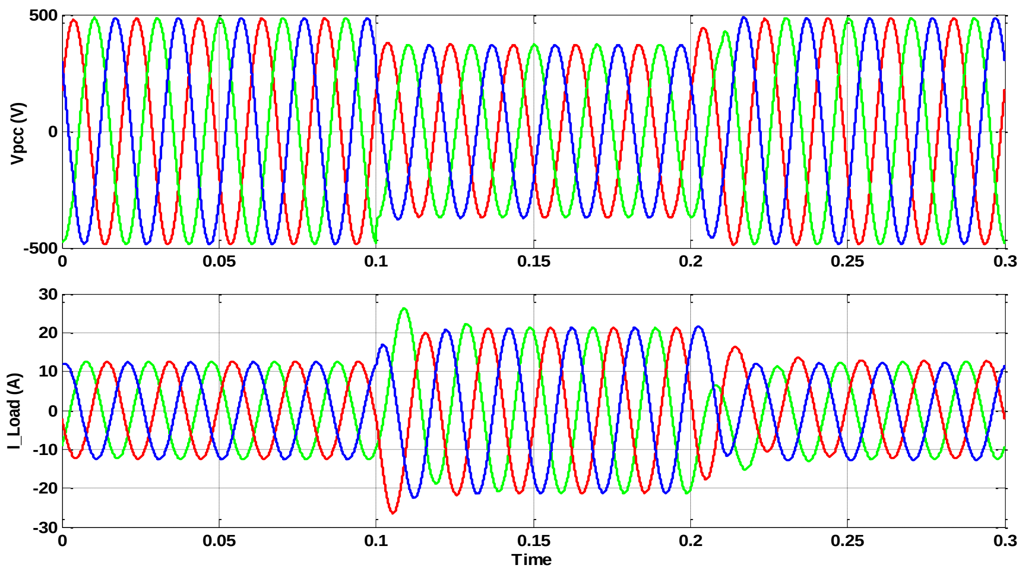

***Figure 9 (a):** Voltage and Current at PCC without UPFC*

The Figure.9 (a) demonstrates the variety in the voltage and current at PCC when the framework is exposed to blame. The voltage gets diminished to 400 V and the present esteem gets expanded to 25 A. The genuine gets expanded and receptive power gets diminished when blame happens at 0.1s to 0.2s. Genuine and responsive power ends up 1.4 MW and-0.4 MVar as appeared in figure 9 (b) and there is likewise an adjustment in voltage diminishes up to 400V as appeared in Figure 9 (a).

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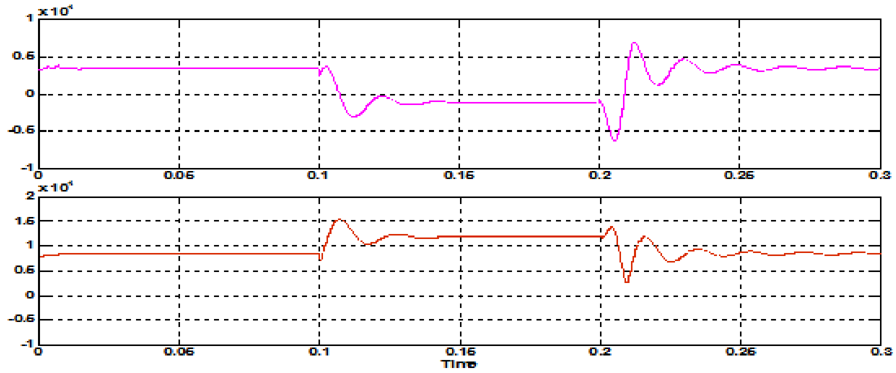

Figure 9 (b): *Real and Reactive powers without UPFC*

The magnitude of voltage gets decreased from 440 V to 350V when the system suffers from fault which is shown in the Figure 9 (c).

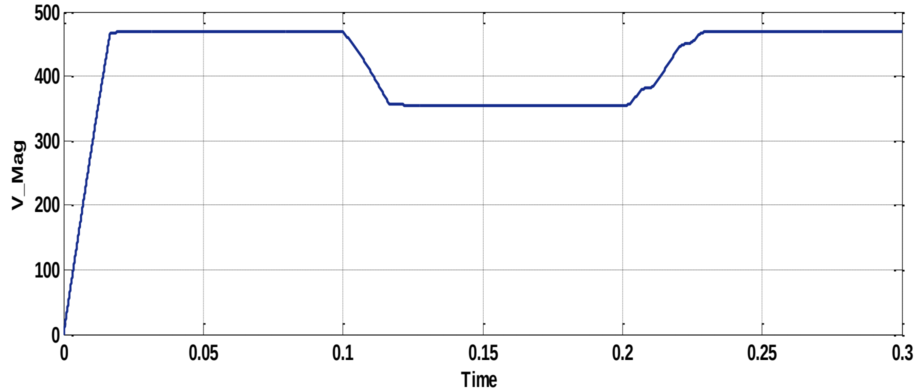

Figure 9 (c): *Magnitude of voltage without UPFC*

Response of the System with UPFC

The Figure.10 (a) - 10(d) indicates when the framework blame is cleared by UPFC. At the point when the framework associated with the UPFC then receptive power is infused to the framework and there is a slight mutilation for a little timeframe (for example UPFC's on time) and the voltage winds up stable (in Figure.10 (an) after a little irritation (voltage ends up 440V when UPFC is associated) and current additionally achieves its consistent position at 10 A. In this way the UPFC will give receptive power when framework is required.

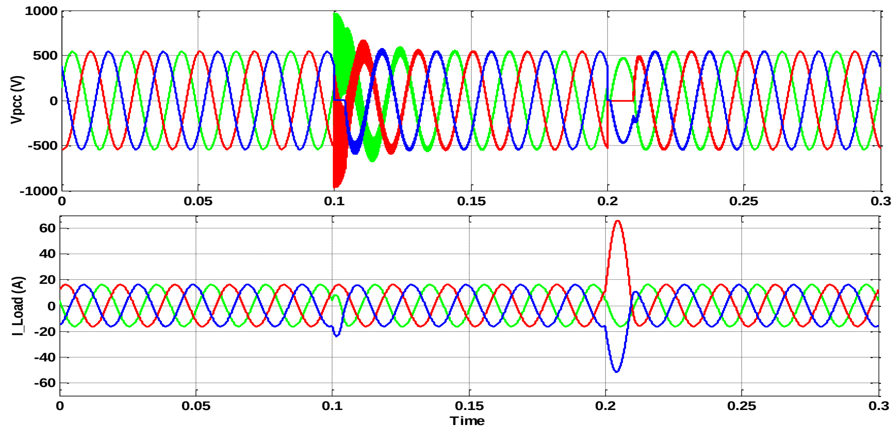

Figure 10 (a): *Voltage and Current at PCC with UPFC*

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When the system is connected with UPFC, it will inject reactive power and it come back to flat position as shown Figure.10 (b) and the real and the reactive power becomes constant at 0.2.

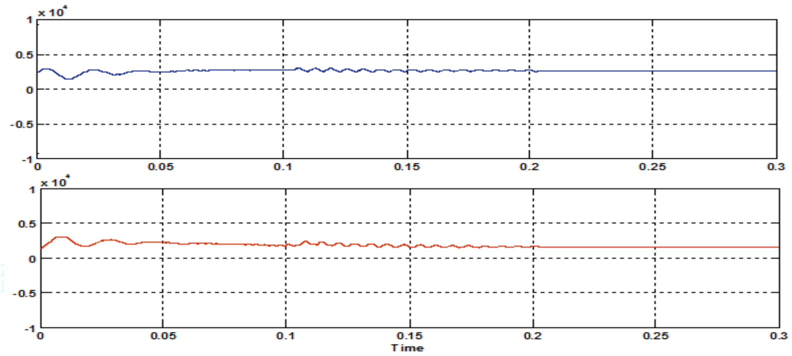

Figure 10 (b): *Real and Reactive powers with UPFC*

The magnitude of voltage becomes normal and reaches the value of 520V when the UPFC is connected to the system which is shown in the Figure.10 (c).

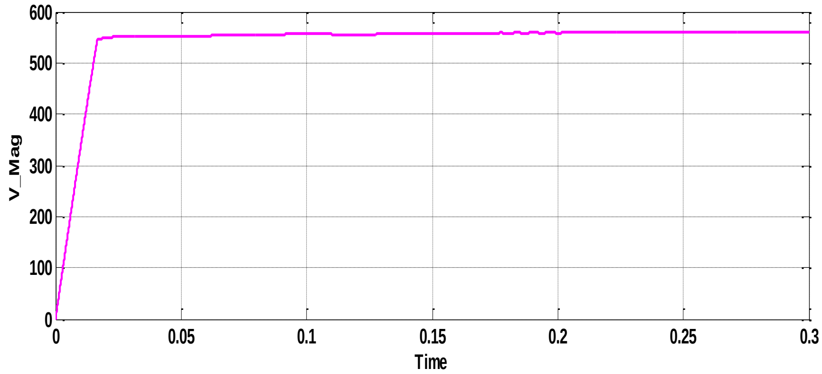

Figure 10 (c): *Magnitude of Voltage with UPFC*

The Figure.10 (d) shows the DC link capacitor voltage gets increased to 620V after the compensation from the UPFC.

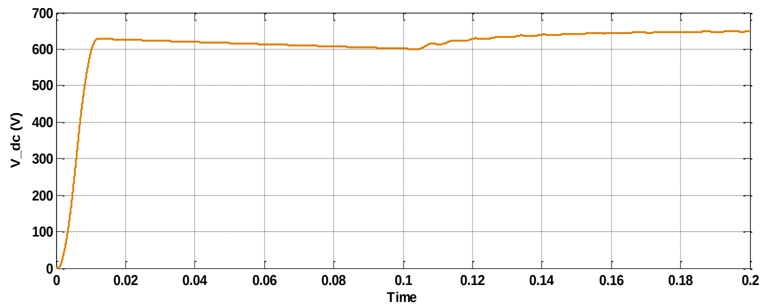

Figure 10 (d): *DC link voltages with UPFC*

At the point when voltage drop at the PCC happens at t =0.1s to 0.2s, the UPFC is useful in capacitive mode where the UPFC terminal current will lead the transport voltage. Therefore, responsive power is immediately infused by UPFC to help the framework and to control the voltage at the PCC as appeared in Figure.10 (a).

COMPARISON TABLE FOR THE RESULTS WITH AND WITHOUT UPFC

Table 2: *Comparison table for the results*

	Grid Voltage (V)	**Load Current (A)**	**Real power (P) (MW)**	**Reactive Power (MVar)**
Without UPFC	380	25	1.4	-0.4
With UPFC	460	10	0.35	0.2

CONCLUSIONS

This paper proposed a control approach for the Unified Power Flow Controller for the enhancement of Low Voltage Ride Through capacity [LVRT] of doubly fed induction generator [DFIG] based wind turbine associated with a network. The DFIG has been considered as a wellspring of intensity from the wind turbine and UPFC has been constrained by Fuzzy Logic Controller. The total framework including the wind turbine and Unified Power Flow Controller [UPFC] is demonstrated utilizing MATLAB Simulink. UPFC is utilized to repay the responsive power where there is a plausibility of voltage list in the framework. At the point when Voltage sag happens in the framework, the Unified Power Flow Controller (UPFC) infuses responsive capacity to keep up the voltage profile in framework. The outcomes are checked for the two cases, with controller and without UPFC controller.

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