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LOW VOLTAGE RIDE THROUGH CONTROL STRATEGY FOR DFIG BASED WIND TURBINE WITH FUZZY CONTROLLER

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Short Profile

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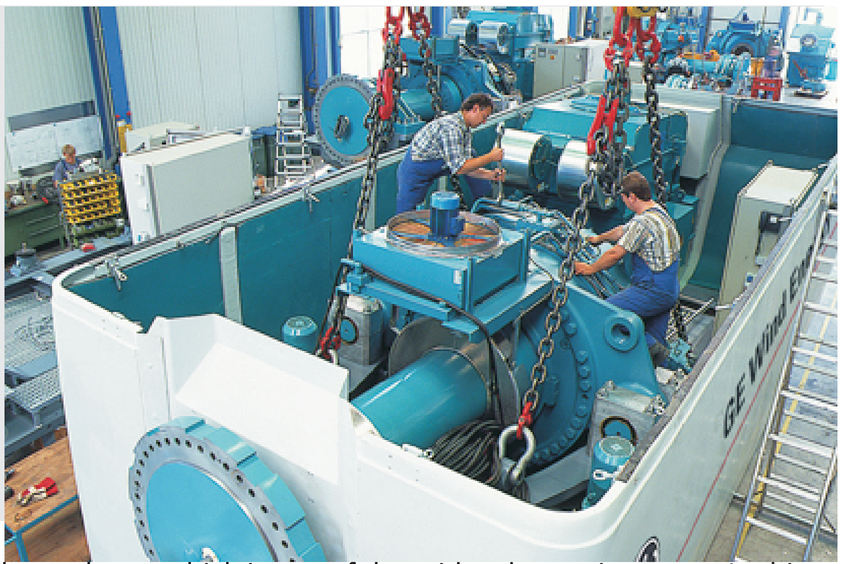

ABSTRACT:
This paper deals with the Low Voltage Ride Through (LVRT) control scheme for the Doubly Fed Induction Generator (DFIG) based Wind Turbine (WT). Due to the increase in power demand the renewable energy source are used to compensate the demand. In this, wind energy system plays a vital role. The rise in penetration of wind source leads to the study of LVRT. The wind system is required to be connected with the grid even under low voltage, which is one of the grid code requirements. In this paper a control scheme is designed to have the LVRT capability, where the control scheme provides stable operation even during voltage dip condition. The control scheme is used to integrate the Wind system with the grid during voltage dip condition. The analysis is made in MATLAB/ SIMULINK and the results are discussed.

KEYWORDS
Low Voltage Ride Through, Doubly Fed Induction generator, Wind turbine.

INTRODUCTION

Now a days, wind energy has become a viable solution for energy production, in addition to other renewable energy sources. One way of generating electricity from renewable sources is to use wind turbines that convert the energy contained in flowing air into electricity. Among all the renewable energy sources the wind source is the widely used source to compensate the power demand in large scale application. One of the new requirement in the Wind Energy Conversion System (WECS) is to produce the LVRT capability. The Fig 1.1 shows the voltage limit curve which describes the LVRT capability according to Grid code requirements[3].

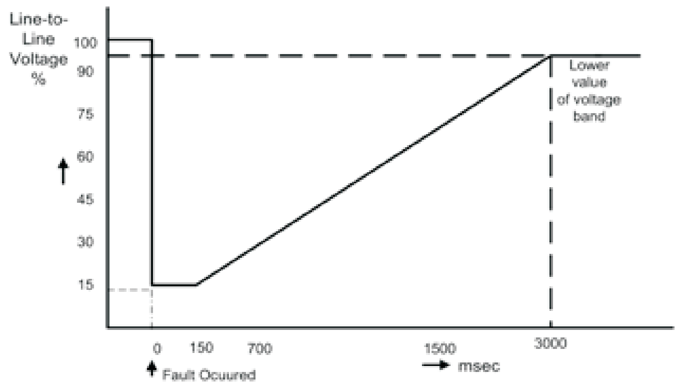

Fig 1.1 Voltage limit curve to allow wind turbine disconnection

The Doubly Fed Induction Generator (DFIG) based wind turbine with variable-speed variable-pitch control scheme is the most popular wind power generator in the wind power industry.

II DOUBLY FED INDUCTION GENERATOR

A.Operation of DFIG

The DFIG consists of stator windings which is directly connected to the grid. The wound rotor windings are connecte to the power converter. The DFIG is selected for the WT due to its flexibility in variable speed range operation and lower cost of power converter. The AC/DC/AC converter is basically a PWM converter which uses the sinusoidal PWM technique to reduce the harmonics present in the wind turbine driven by DFIG. The AC/DC converter at the rotor side is used mainly to have the controlled frequency operation. The rotor side converter acts as a rectifier, it rectifies AC to DC that is stored in the DC bus energy storage. The grid side converter acts as a inverter and it produces AC output that matches the frequency and voltage to meet the grid code requirements[1].

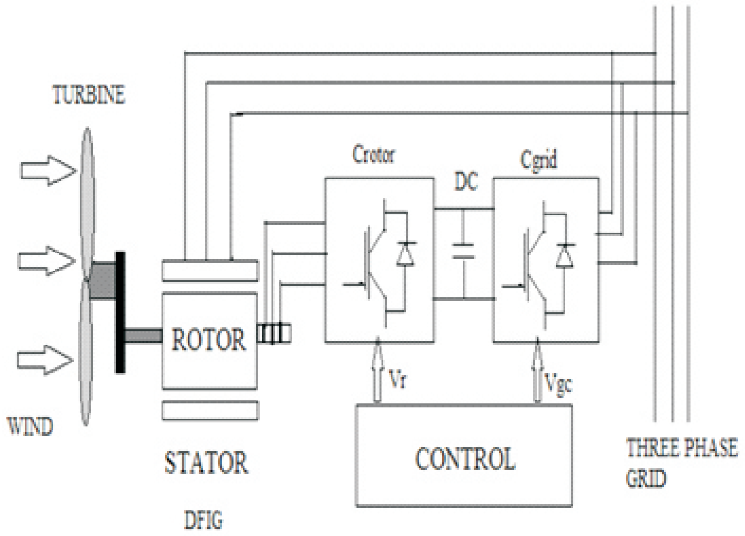

Fig 1.2 Basic block diagram of DFIG Wind Turbine

A.DFIG Modelling

In Matlab Simulink synchronous generator is used in this system and it has the same electrical concept of a PMSG since the field excitation is assumed to be constant. The generator is represented in rotationally rotor reference frame (dq frame) and all the electrical quantities are seen from the stator[10][11].

The voltage equations for the direct and the quadrature axis is given in equation (1) and (2) as follows

$$Vd = Rsid + \frac{d}{dt}\Phi d - \omega r\Phi q \qquad (1)$$

$$Vq = Rsiq + \frac{d}{dt}\varphi q - \omega r\varphi d \qquad (2)$$

The voltage equations for the field is given in equation (3),(4),(5),(6)

$$V'fd = R'fdi'fd + \frac{d}{dt}\varphi'fd \qquad (3)$$

$$V'kd = R'kdi'kd + \frac{d}{dt}\varphi'kd \qquad (4)$$

$$V'kq1 = R'kq1i'kq1 + \frac{d}{dt}\varphi'kq1 \qquad (5)$$

$$V'kq2 = R'kq2i'kq2 + \frac{d}{dt}\varphi'kq2 \qquad (6)$$

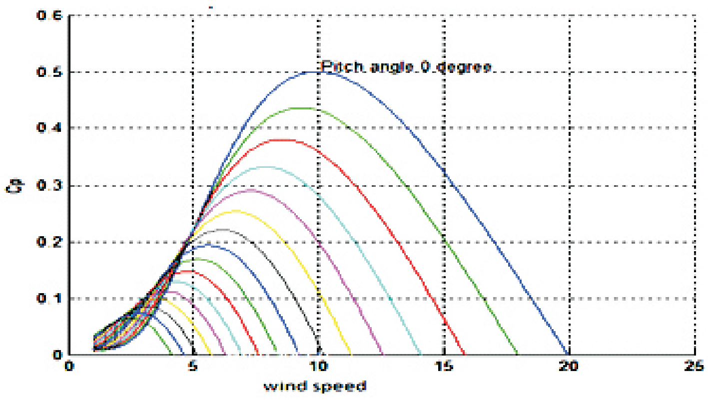

Fig 1.3 Power angle curve for DFIG WT

The power angle curve explains the pitch angle of the WT. When the pitch angle is 0 the maximum output can be attained from the turbine, as the pitch angle of the blade increases the maximum output will decreases according captured wind.

The direct and the quadtrature angle are gien as follows;

$$\varphi d = Ldid + Lmd(i,fd + i'kd) \quad (7)$$

$$\varphi q = Lqiq + Lmqikq \quad (8)$$

$$\varphi' fd = L'fdi'fd + Lmd(id + i'kd) \quad (9)$$

$$\varphi' kd = L'kdi'kd + Lmd(id + i'fd) \quad (10)$$

$$\varphi kq L'kq1i'kq1 + Lmqi'q \quad (11)$$

$$\varphi kq2 = ikq2i'kq2 + Lmqi'q \quad (12)$$

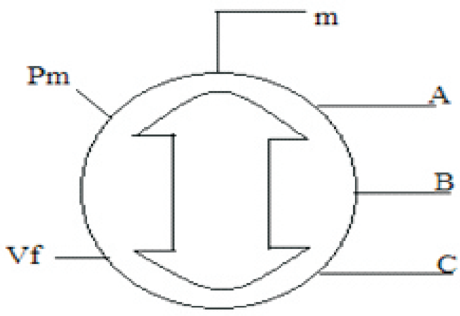

Fig 1.4 Synchronous generator used in Matlab Simulink

III CONTROL SCHEME

A.Conventional Crowbar Protection

Additional crowbar resistors will be inserted into the DFIG rotor circuits the over current and the Rotor Side Converter (RSC) will be disabled during voltage dip conditions. Although the Crowbar solution guarantee successful fault ride through , it will however involve additional investments, energy dissipation by Crowbar resistors and particularly control of active and reactive power. When the Crowbar is activated it absorbs reactive power which is dangerous to the system[2].

The crowbar protection consists of three phase diode bridge in series with a bypass resistor and a switch. The operation of the crowbar is explained as follows;

Activated : Sc=1
Deactivated: Sc=0

The crowbar protection can be modeled with the simple equation as

$$V_{crow} = S_c R_{crow} I_{crow}$$

B.Rotor Side Converter

The rotor side converter (RSC) is used to control the torque production of the DFIG through direct control of the rotor currents. The RSC does this by applying a voltage to the rotor windings that corresponds to the desired current. The RSC will operate at 15 varying frequencies corresponding to the variable rotor speed requirements based on the wind speed [4].

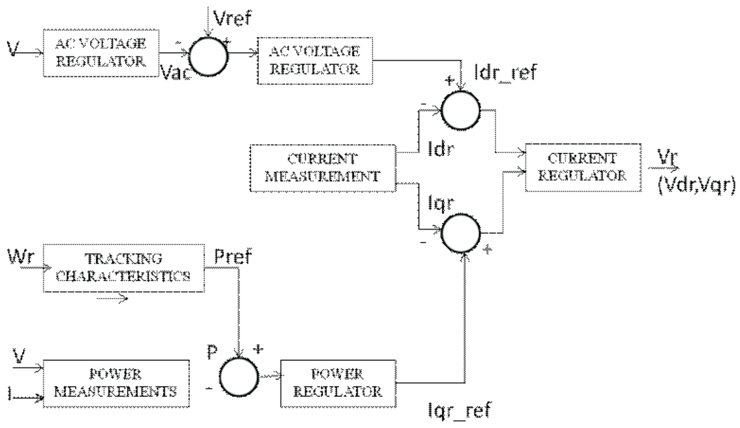

Fig 1.5 Rotor Side Converter Control

The rotor side converter can use either a torque controller, speed controller, or active power controller to regulate the output power of the DFIG. This output power is controlled to follow the wind turbines power-speed characteristic curve. Essentially, any given wind speed corresponds to an amount of available power that can be extracted from the wind. In order to extract this power most efficiently, the optimal tip-speed ratio must be kept before rated power is reached, corresponding to a different rotor speed for each power level.

This calculation is done for any given wind turbine, resulting in a unique power-speed characteristic curve. The actual output power from the generator, plus all power losses, is compared to this reference power from the power-speed curve. Typically a Proportional-Integral (PI) controller is used to control the torque, speed, or power to its reference value. Whichever controller is used, the output of the controller is the reference rotor current required to generate the desired torque or power, or to obtain the desired speed. An inner PI control loop is then used to control the rotor current error to its reference value, with the rotor voltage reference as the controller output the rotor current can also be used to control the reactive power production of the DFIG. The details of both the torque and reactive power control will be elucidated in the section Control of the DFIG Machine.

C.Grid Side Converter

The grid side converter is used to regulate the voltage of the DC link between the two converters. The GSC contains on outer loop control that controls the DC-link voltage, attempting to control it to nominal value. An inner PI control loop controls the GSC current. Commonly the GSC acts to set Qgc = 0 and maximize active power output. As the GSC is connected directly to the grid, it must output power at a fixed frequency corresponding to the grid frequency[4].

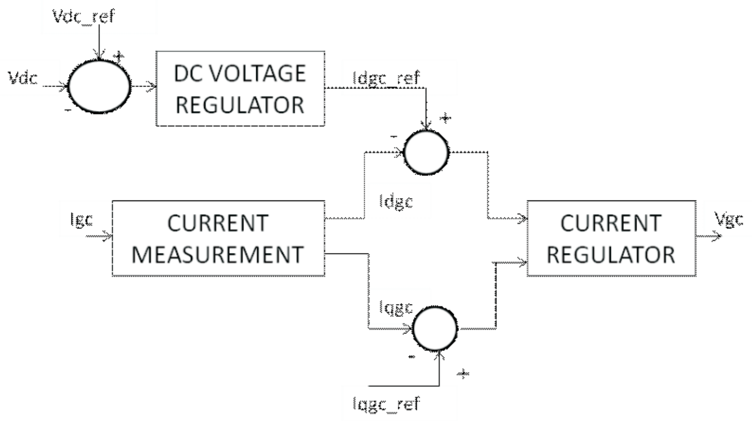

Fig 1.6 Grid Side Converter Control

V FUZZY LOGIC CONTROLLER

Fuzzy Logic is based on logical functions. The concept of Fuzzy logic is derived from set theory[10].There are several controllers which provide efficient control for linear systems. In case of nonlinear systems Fuzzy Logic Controllers are used. Fuzzification, rule creation, and defuzzification are the steps involved in fuzzy logic system. The input to the fuzzy controller is in the form of real variables. In the process of fuzzification the real variables are converter into fuzzy variable and each fuzzy variable are represented by membership function.

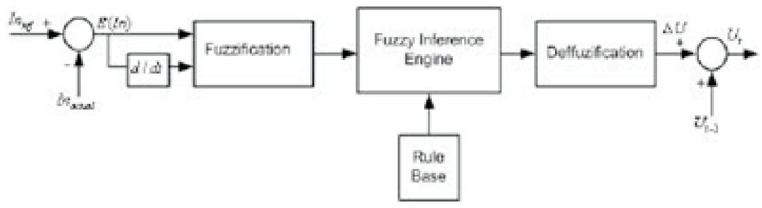

Fig 1.7 Block diagram of Fuzzy Controller

The second step is formation of fuzzy rules, fuzzy rules are based on definite decision i.e., in the form of IF-THEN. Finally when all the operations of control is over at the last stage the fuzzy variables are again converted into real variables which is as known defuzzification.

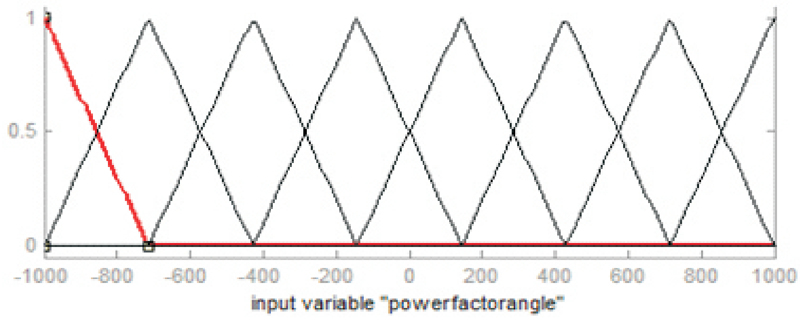

Fig 1.8 Membership function for power factor angle

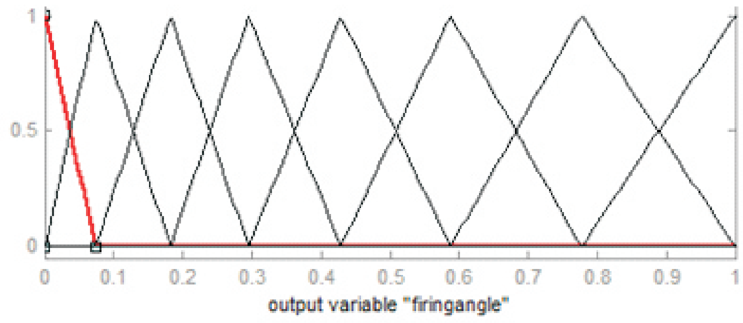

Fig 1.9 Membership function for firing angle

VI SIMULATION RESULTS

The analysis is done in MATLAB/SIMULINK for the voltage dip conditions. The results are obtained as follows,

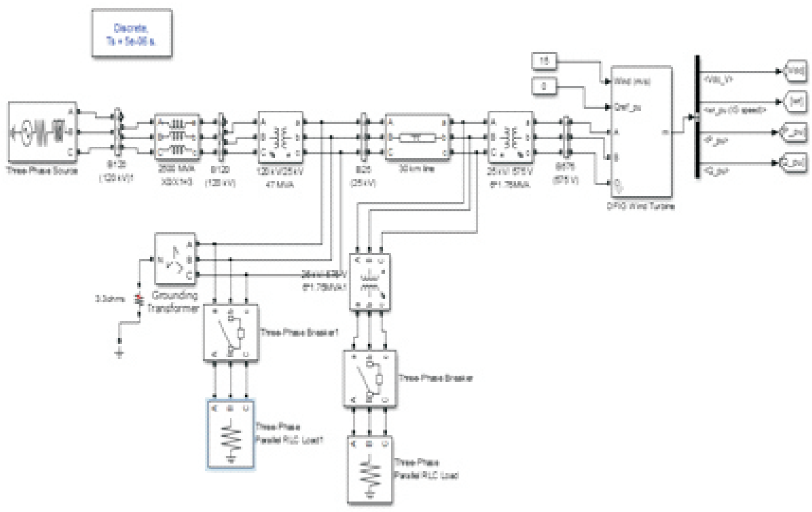

Fig 1.10 Simulink block diagram for DFIG based WT

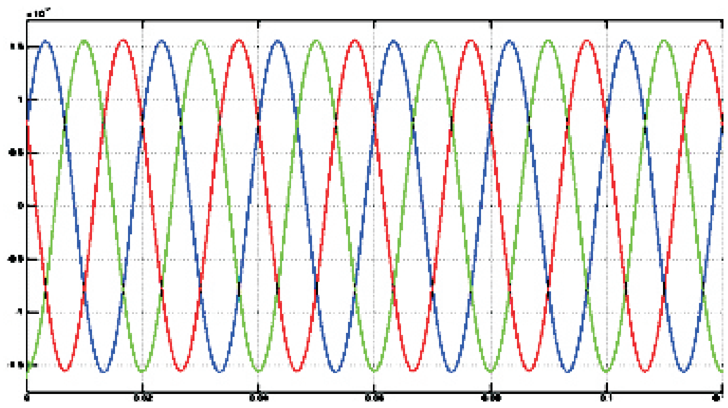

Fig 1.11 Source voltage without voltage dip

Fig 1.11 and 1.12 shows the source and the load voltage without voltage dip. The nominal voltage flows through the load.

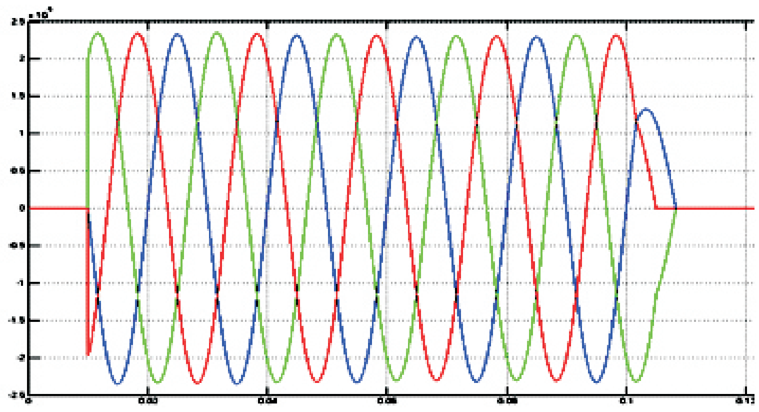

Fig 1.12 Load voltage without voltage dip

Fig 1.13 shows the source voltage waveform with voltage dip. Here the control scheme is not activated. It can be noticed that when the dip occurs the nominal voltage flow is not attained at this case.

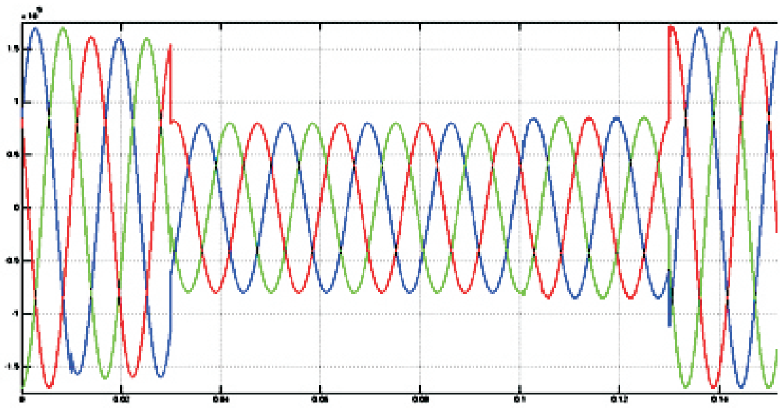

Fig 1.13 Source voltage with voltage dip(without control scheme)

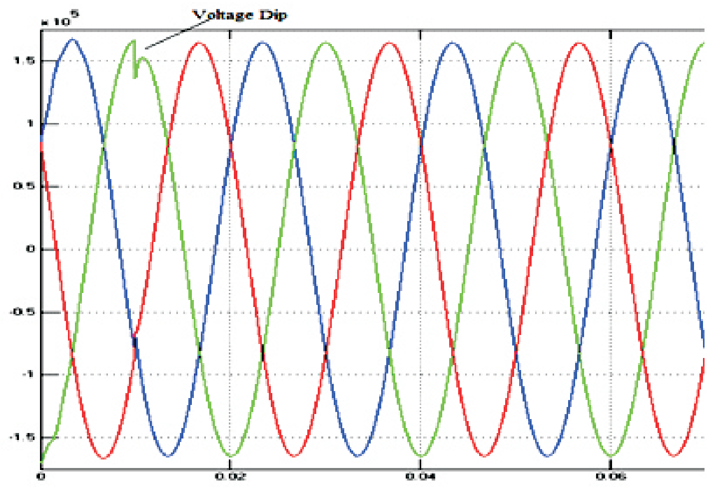

Fig 1.14 Source voltage with voltage dip (With control scheme)

The Fig 1.14 and 1.15 shows the source and the load voltage with control scheme for voltage dip condition. It can be seen that in Fig 1.10 when dip occurs, the nominal voltage is reached at instance since control scheme is activated.

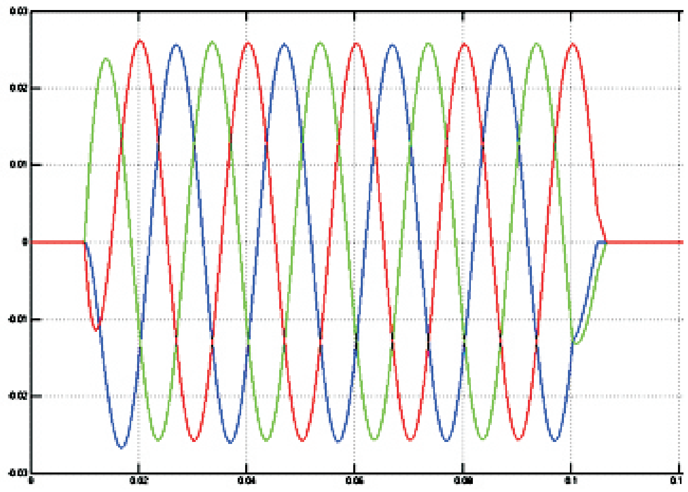

Fig 1.15 Load voltage with voltage dip (with control scheme)

VI CONCLUSION

The analysis is done using MATLAB/SIMULINK for the DFIG based WT. The output waveform are obtained and analysed for the voltage dip condition. The output is analysed for both with and without control scheme.

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