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DFIG based WT harmonics Analysis subjected to Diverse Transmission Fault

Manoj Kumar Baral[1], Radhakrishna Das[2], Abhipsa Sahu[3]
[1]*Assistant Professor, Department of Electrical Engineering, BIT, Bhubaneswar, Odisha, India*
[2]*Assistant Professor, Department of Electrical Engineering, GEC, Bhubaneswar, Odisha, India*
[3]*Assistant Professor, Department of Electrical Engineering, GIFT, Bhubaneswar, Odisha, India*

Emails: mbaral1800@gmail.com, rups.krishna@gmail.com, sahuabhipsa8@gmail.com

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Abstract

This paper is focused on harmonic analysis for an energy conversion system using wind power (WECS) based on a Double Fed Induction Generator (DFIG). A Frequency converter is coupled back to back is used to excite the rotor winding and stator winding excited by different electrical networks. This work also focuses on harmonic distortion based on the DFIG Model. This approaches also analyzed on the basis of different kind of Line and Ground faults of Transmission line. The research work is Conducted using Simulink software with the SimPower System. The MATLAB simulation shows a major work in the design, study, and assessment of different controller based power electronic converter. A Research Case study for a 5 Mega Watt renewable wind turbine mill is Described , which is Designed for the load flow calculation of harmonic

1. Introduction

Harmonics in termed with Power quality in real world represents the rate of filtered sinusoidal quantities (i.e.) Voltage and current. Power quality is a crucial factor in designing profit-making and industrialized power system. An ideal sinusoidal electrical source should be deprived of any kind of variation in its waveform. Harmonic distortions are the variation in waveform of current or voltage in its ideal form. Harmonic distortion is caused by many reasons. It should be the main concern of engineers to eliminate the harmonics from power system. In the current scenario the complexity added to power system designs in various fields has given rise to harmonic distortion as well. This paper has analyzed the effects of Harmonics in different fault condition and the required stages to diminish its effects in the proposed power system, which includes the Harmonic diminution techniques to handle the power quality and the performance analysis is represented by simulation.

Speed variation, transmission stability and support of grid during different fault in power systems; it has increased the demand of DFIG wind turbines. The accumulation of power electronics devices and Analog and digital controllers has prepared DFIG a robust solution in power generation.

The proposed system has use of Large-sized wind turbines namely fixed-speed and not constant-speed type wind turbines. The system is simulated and analyzed for fault studies by using vector strategy, when the location of fault is changed (Pradhan and Srivastava S, M, and R). Some systems has been subjected to research on methods for manipulative THD of digital sinusoidal waveform and the representation of conjectural formula of the relation of

THD, different time domain study with the computation outcome have been estimated (Tang and Ooi S, M, and R Zhang).

Six step switching Techniques (Iyer and Muthu), Low Voltage DC transmission Line can be implemented as speed-sensor-less drives of the Double Fed Induction Generator wind-turbine (Qiao and Harley Yasa, Sozer, and Mese Lu and Ooi Xu and Wang Dubey et al.). Analysis of Harmonic of a DFIG has also been find in (Nath, Dey, and Chakrabarti). Winding's function Theory has been applied for internal faults in PMSG (Emmanuel et al. Kyaw, Min, and Ramachandaramurthy). PWM Technique and space vector PWM (Sørensen et al. Kheshti et al.) are the techniques used to create the Harmonics.

2. Background

2.1. Double Fed Induction Generator (DFIG)

DFIG are comparable to AC generators, having superfluous features that permit them to run at asynchronous speeds. As the wind speed variation is instantaneous, DFIG is suitable for large variable speed type wind turbines. When a breeze of wind hits, the blades attempt to induce speed, but a synchronous generator can't speed up as it is sealed to the speed of the powergrid which results in the occurrence of large forces in the core, gearbox and generator as the power grid drives back. This causes wearing and damages the mechanism. If the turbine is permitted to catch speed instantaneously when hit by slightest pressure of wind, the pressure level decreases and the frictional power from the wind is changed into useful electricity. For small house and farm wind turbines when speed differs, by the use of an inverter it obtains the required AC output of preferred frequency by converting the DC output of the generator irrespective of its frequency. As in case of larger system the above mentioned approach is not economic, DFIGs are one key to this problem. DFIG consists of two three-phase windings separately connected to equipment outside the generator on stator and rotor respectively.

2.2. Construction

One winding of DFIG is directly linked to the output, and yields 3phase AC power at the chosen grid frequency. The field winding is connected to 3-phase AC supply at variable frequency. It is adjusted according to required frequency and phase to compensate the changes in speed of the turbine.

In wound rotor machine the double fed machine needs high flux in the air-gap area. As it saturates severely if DFIG operation is considered at rated stator voltage. For this purpose the slip ring strategy is used which affects the robustness of the system as it requires maintenance frequently.

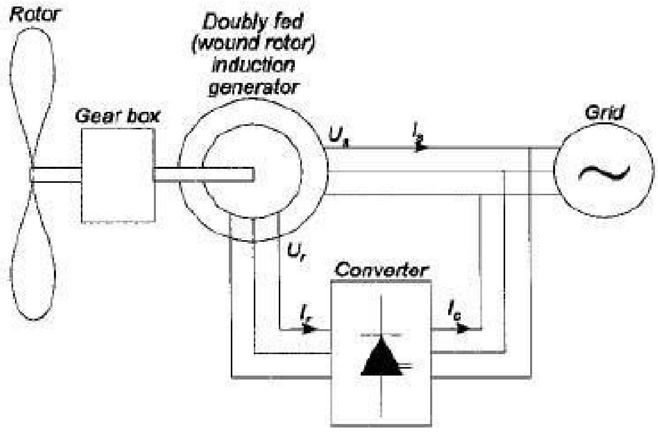

FIGURE 1. FBD of DFIG connected wind turbine

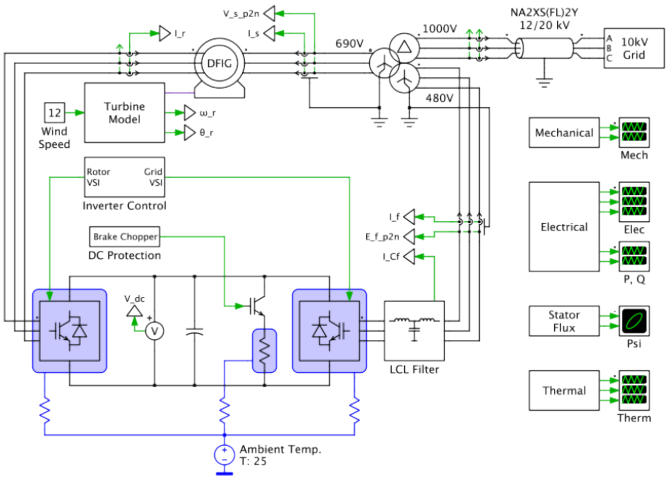

FIGURE 2. DFIG based WT System

Digital Converters are used in DFIG system placed in the rotor side and a proposed control strategy is embedded with the Rotor side the grid. DFIGs are commonly used as IGBT based Voltage Source Converter. On the Output side the Direct Current voltage source is provided by connecting a capacitor meanwhile the stator and rotor windings are connected to three-phase transmission grid and slip ring converter respectively to regulate the output power of the W-T alongside with the bus bar and grid voltages.

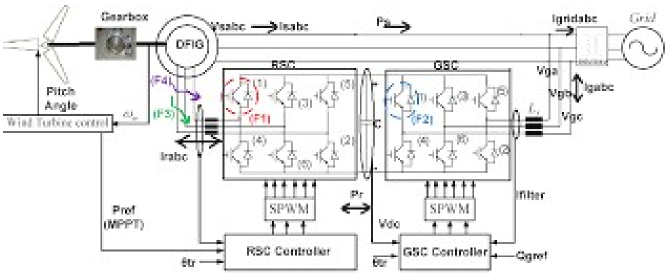

FIGURE 3. Power flow diagram of DFIG based wind turbine

3. Power Flow Diagram

The power flow process represented in Fig. 3operating principle of DFIG system and the electrical parameters used are defined Table 1.

Fig. 3. Power flow diagram of DFIG based wind turbine

The Mechanical and Electrical stator Output power are given by equation (1-2) respectively.

$P_m = T_m m_r$ (1)

$P_s = T_{em} m_s$ (2)

$J = d_w / d_t = T_m - T_{em}$ (3)

$T_m = T_{em}$ (4)

$P_m = P_s + P_r$ (5)

$P_r = P_m - P_s$

$= T_{mCr} - T_{mCs}$

$= -sT_{mCs}$

$= -$ sPs (6)

Here's' is termed as the slip of the generator and is given by

$s = (c_s - c_r)/c_s$ (7)

Decreases hence resulting reduction in the sub-synchronous speed (N_s) of operation, Power is equal as the input power (P_{input}) and the wind turbine Speed(N_{wind}) depends on how much Power absorbed or generated during steady-state operation by an ideal converter

For efficient operation and to govern the Reactive power (P_{xr}) or the Grid station voltage, the generation and absorption of reactive Power can be carried out by both Rotor and Grid side converter.

4. Line Faults in Transmission Systems

Electrical power system covers a wide range in sectors involving generation, transmission, distribution of electricity along with load systems. Groupings of faults is based on several factors such as short circuit condition in power grid whose end results is unembellished cost-effective losses that shrinks the dependability of the electrical system. Electrical fault is a unpredictable phenomenon, caused by apparatus failures as in case of static and rotating electrical machines which may be due to human errors or any ecological circumstances. These faults disrupt the electric movements that results in apparatus damages which may be the reason of casualty. The mainly familiar type of unsymmetrical fault in a power system is Single L-G fault which is around 60-75% of the types of fault occurring in a system.

4.1. Line-to-Ground fault (L-G)

L-G fault causes the conductor to build drop a line with earth. Around 15 to 20 percent of faults are L-L-G that causes two conductors to touch the surface. Almost 5%- 10% of the faults are Single Line to Single Line faults which make two conductors to make contact with each other, mostly occur when there is fluctuation of lines due to wind. These are the disturbed faults that cause the system impedance standards to differ phase wise causing the flow of unbalanced current in phases, which are then analyzed by per phase basis related to three-phase balanced faults as these are hard to carry out when considered together.

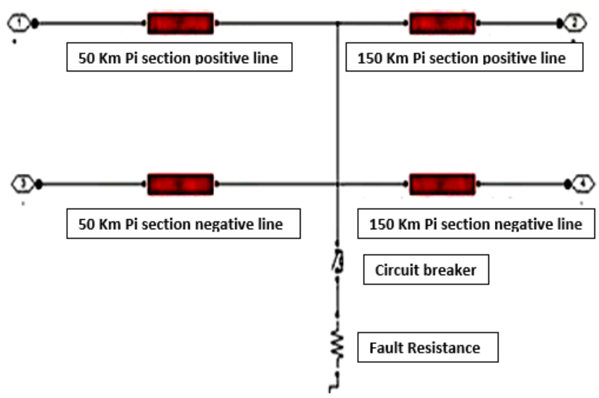

FIGURE 4. Positive L-G Fault

4.1.1. Voltage and Current Distortion

Current Harmonics are triggered by non-linear loading such as Thyristor drives, induction boilers, etc. It affects the distribution system which gets overloaded as the waveform of the other frequencies use up measurements without any contribution in supplying power to the load.

Voltage Harmonics are triggered by the current harmonics which garble the voltage waveform. It disturbs the total system along with the loads triggering them.

TABLE 1. Power Flow Parameters

Sl. No.	Notations	Details
1.	Pm	Output Power output of WT (Mechanical)
2.	Ps	Output Power of Stator(Electrical)
3.	Pr	Output Power of Rotor (Electrical)
4.	Pgc	Total Output Power (Electrical)
5.	Tm	Applied Torque to rotor (Mechanical)
6.	T em	Electromagnetic Torque
7.	Nr	Rotational speed (rotor)
8.	Ns	Synchronous Speed of WT
9.	J	WT inertia coefficient

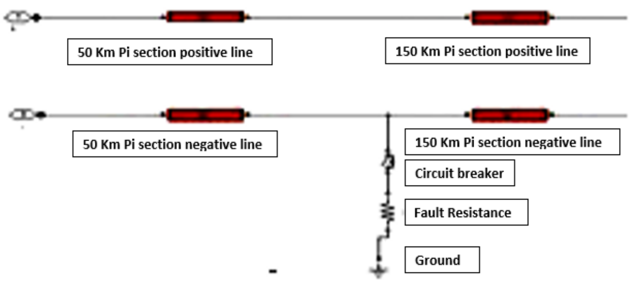

FIGURE 5. Negative L-G Fault

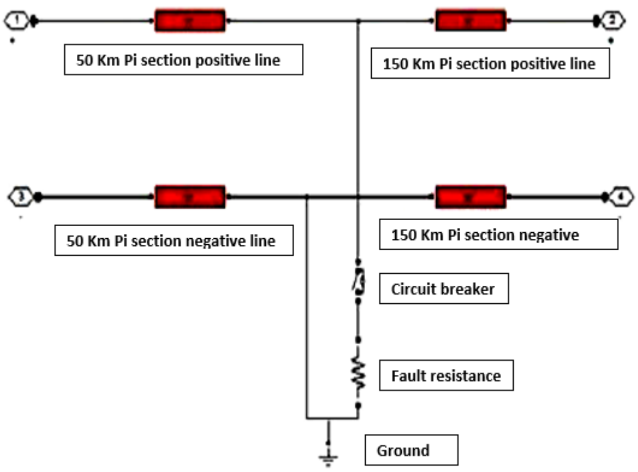

FIGURE 6. L-L-G Fault

4.1.2. Total Harmonic Distortion (THD)

Total Harmonic Distortion is a protracted form of Electrochemical Impedance Spectroscopy. Both techniques are built on a sinusoidal AC signal which is functional to an electrochemical system. The excitation signal E can be articulated in relations of frequency on top of time t.

4.1.3. Simulation and Results

Analysis of Harmonic for Double Fed Induction Generator wind Turbine has been studied for calculation of sudden rise in voltage or sudden rise in current because of different fault conditions in Power Transmission Line. For detailed study the turbine parameters are also considered as from Table-2.

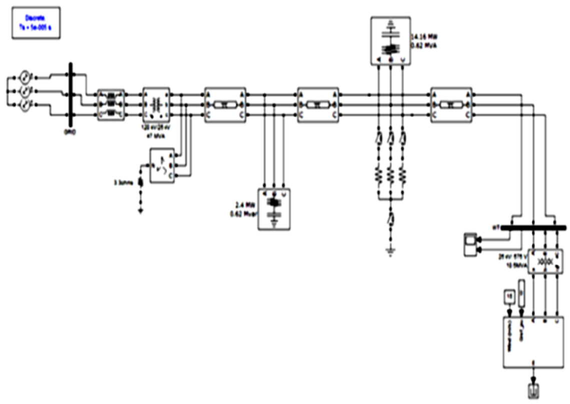

FIGURE 7. Simulation Model of Double Fed Induction Generator system

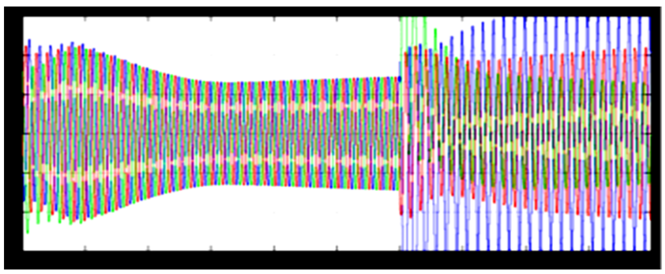

FIGURE 8. Current output for L-G fault

It is clear from the Current output for L-G Fault figure that at Time 0.62 sec, Disturbance is found in the phase A (Shown in Green colour), and Current magnitude can found in the phase B (Shown in Red Colour) at - 0.335, after that it rises to 0.609 sec and at that point current is 2.98 p.u. then current started

TABLE 2. **Parameters of Wind Turbine**

S. No.	Parameters	Values
1	Wind turbine in Numbers	6
2	Nominal mechanical output power (Watt)	1.666
3	Running Speed of wind (Cp max in m/s)	12
4	Initial Speed of speed (m/s)	12

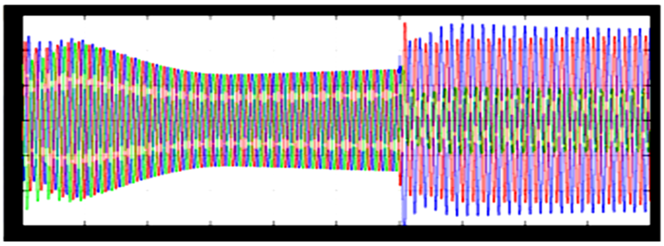

FIGURE 9. **Current output for L-L-G fault**

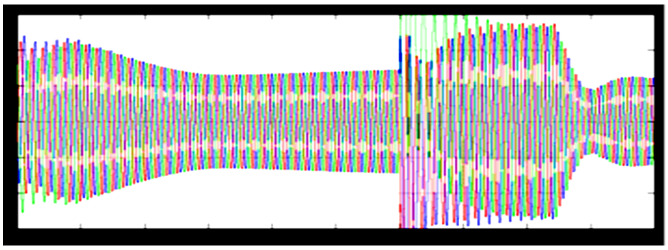

FIGURE 10. **Current output at wind farm for L-L-L-G fault.**

decreasing and achieve maximum negative value of 0.702 p.u. at 0.767sec. At the time of insertion of Disturbance will be in phase A.

The phase C (Shown in Blue Colour) is -0.566p.u. , and after that it started increasing until 0.62ts at that point the current is 1.12p.u. The current started decreasing suddenly to its maximum negative v a l u e of -1.12 at 0.867s. At Starting of Fault in transmission line the phase A current is 0.755 p.u, then current Decreases until 0.69s at that point, The c u r r e n t Value i s -3.77 p.u. The Current Value Reaches its maximum Positive value After the value Increase which is 1.70 p.u. In Transmission fault of Line to Ground condition is different from others.

4.2. L-L-G (Double line to ground fault)

In Phase-B LLG fault introduced at 0.62 sec and current (Mentioned as Red Colour), the current starts increasing from-0.367 p.u. to maximum 3 p.u with a time length of 0.009sec from the Starting of fault at 0.611s and then it starts decreasing to negative value which maximum in reverse that is of -.781 at 0.781sec and in the phase C (Shown as Blue Colour) varies from-.402 to 1.20 p.u. then starts decreasing up to the –ve value which is maximum that is -1.21p.u. at 0.982sec. An Over damped Current present in Phase-A.

4.3. L-L-L-G (Triple line to ground fault)

L-L-L-G disturbance fault is introduced at 0.62sec and In phase-B current is present (mentioned in Red Colour) changes from -0.379 to maximum +ve value of 2.98p.u. at 0.612sec. Current is maximum –ve value -0.731 is found at 0.765sec. At Time 0.612sec LLLG fault is found in transmission line and current is in the phase-C (Shown in Blue Colour) is -.518. The Vibration attain their +ve v a l u e w h i c h i s maximum that is 1.21 at .98sec and -ve maximum -1.17 at .982s. At Time .6s and it can be observed LLLG fault is .931 which noticed in Power Transmission line (Mentioned as GREEN COLOUR). Oscillations occurred having maximum positive value of 1.71 at 0.881sec and maximum negative value of -2.99 at 0.606sec continuously. It can be concluded that, the outcome result of L-L-L-G fault is higher than L-L-G and L-G fault. As a result we can found in Phase-A and Phase-B always hampered more. Line to Ground Fault is always affects Single phase.

5. Harmonic Analysis Outputs

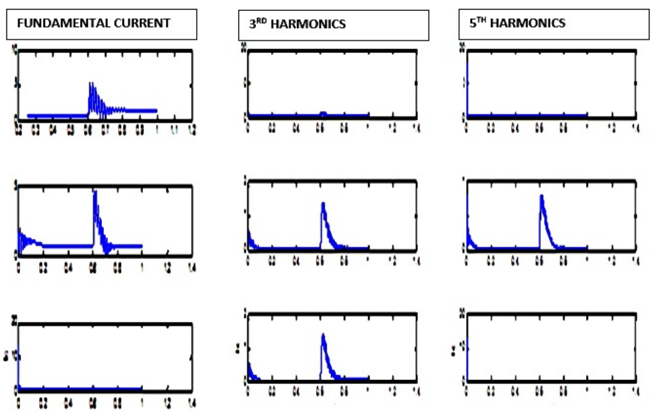

FIGURE 11. **THD of Current in L-G fault**

In the current waveform an extreme transform appears when transmission fault occurs in any phase to Ground. Third harmonics wave and Fundamental Wave carries the maximum fault current and at same time higher order harmonic carries a small fault current. Time of L-L-G faults, maximum oscillation occurred in the affected lines. In L-L-L-G a peak current draws in the odd harmonic of faulted phase along with the transient.

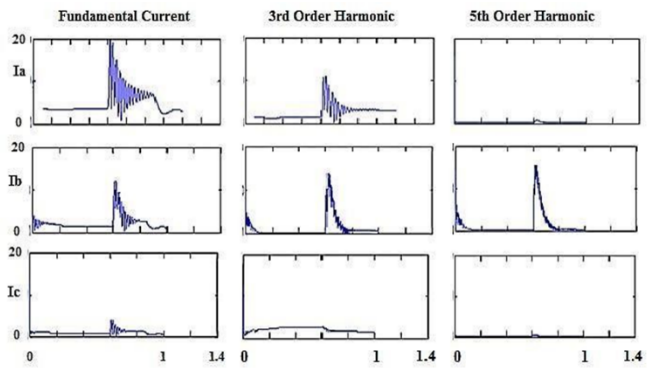

FIGURE 12. **THD of Current in L-L-G fault**

THD is zero before the fault condition which can be find out from the figure and then L-G fault occurs at 0.62sec. At 0.6sec it is,0.554 and THD is maximum at 0.541 and obtained at 0.617sec. L- L-G fault occurs at 0.6sec. Total Harmonic Distortion is null as it is obvious from the figure before the fault, at 0.62it is, 0.203 and Total Harmonic Distortion is peak 0.696 obtained at 0.694sec. L-L- L-G fault Found clearly at .6s .and Before the fault, Total Harmonic Distortion is zero as is understood from the figure. Maximum THD is through the transients diminished out after some time period, the power system may dropped out of synchro and the statistical data, Total Harmonic Distortion of L-L-G fault is minimum among the L-G, L-L-G, L-L-L-G.

5.1. Total Harmonic Distortion analysis of DFIG

Total Harmonic Distortion of L-G fault and Triple L-L-L-G fault are comparable, with Double L-L-G having maximum than THD as compared to Single L-G fault. In the Graphical Representation of percentage THD graph and from the fault analysis the magnitude(in Percentage) of L-G, L-L-G and L-L-L-G fault are 48.77, 51.85 and 61.74 respectively . As Futuristic work Can design and add a fault indicator with signal of all Types of :Line faults comparative to amplitudes from Total Harmonic Distortion analysis.

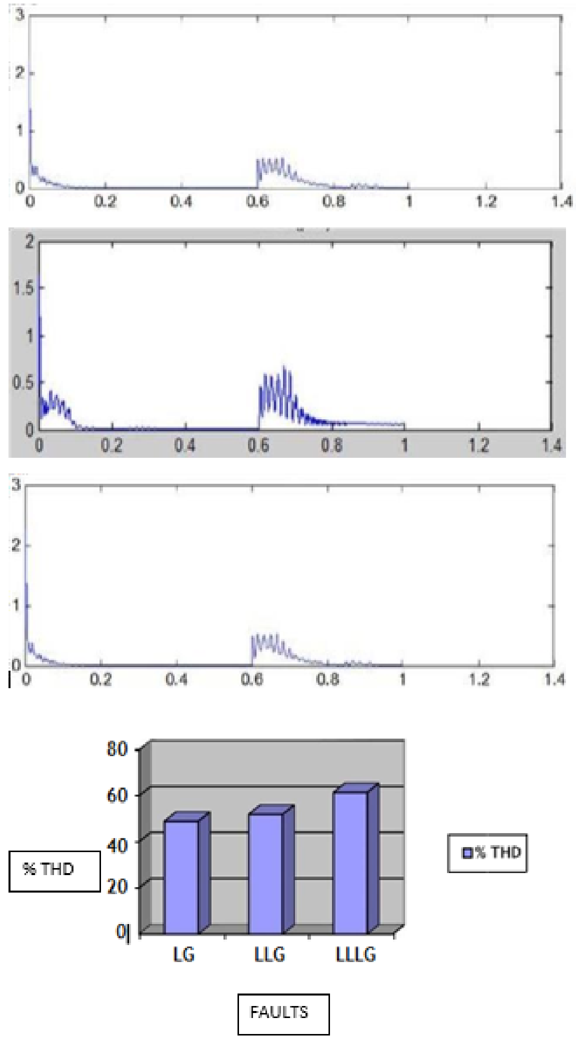

FIGURE 13. **THD of DFIG**

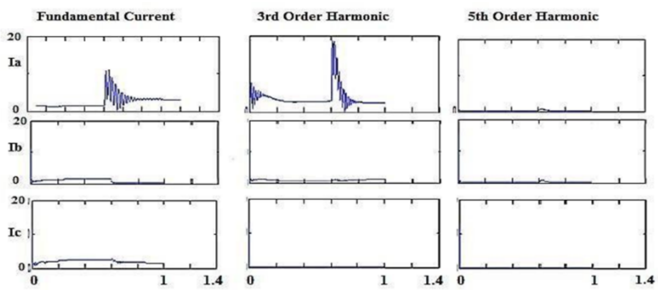

FIGURE 14. **THD of Current in L-L-LG fault**

6. Conclusion

In the wind Turbine power studies, a Simulink model based on the harmonic domain has been analyzed for the induction generator. The simulink model gives the details idea on the harmonic values, and Fault current in the whole Power Transmission System. Total Harmonic Distortion has been analyzed in different fault condition and compared in between all types of Line and Ground Fault. It has been analyzed from the model study that the transient can be calculated and steady-state wind power generation systems connected to Grid, power electronic converters, and non-linear components. As presented in this research work, it is capable to estimate accurately which harmonic impacts straightforwardly on the mechanical dynamics of the wind farm. This work is an loom to compute every harmonic interaction among the induction generator and the different power electronic devices worn out for the interconnection to the power grid. In Transmission Protection part, speedy and true recognition of faults is of utmost importance. This paper work is restricted only to different kind of Line and Ground fault-finding when transmission fault is functional for a certain phase of time period.

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