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Harmonics Detection and its Mitigation in a Doubly Fed Induction Generator based Power System

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Abstract- **Ideally, electric supplying companies are projected to convey sinusoidal voltage having the frequency of constant rate, while the consumers are expected to extract the current in sinusoidal forms with power factor nearly equal to unity. But extensive applications of equipment causing the production of harmonics in domestics and industrial appliances causes some problems in the smooth flow of current and voltage. Especially the usage of non-linear loads is causing the distortion of electric voltage and currents in the power system. Due to these non-sinusoidal flows of voltage and current (harmonics), the performance of overall system is disturbed. So, the detection and mitigation of harmonics is essential. In this research work detection and mitigation of harmonics voltage and currents caused by nonlinear loads using DFIG has been investigated. Multi-reference theory has been used for this purpose.**

Index Terms—**Harmonics, Mitigation, Sinusoidal, Doubly Feed Induction Generator**

I. INTRODUCTION

For sustainable and emission free energy generation, the recent global trend is increasing approaching towards renewable energy sources. Wind energy generation is one of the prominent ways of getting cleaner and emission free energy [1 - 4].

Doubly Feed Induction Generator (DFIG) is one of the major types of generator used in wind energy conversion. It is widely employed for variable speed and medium-high capacity wind turbines. But due to extensive use of the non-linear loads and higher involvement of power electronic devices in energy conversion system, transients are produced in sinusoidal cycles of current and voltage which distort electric current in power distribution system. These harmonics can travel to the other parts of power system and they directly affects the proper functioning of industrial and commercial appliances [2], [3-7].

These current harmonics can cause many effects in power system including overheating, failure of operation of electronic components low power factor. The triplon harmonics can cause overcurrent in neutral fire of distribution system. Opposite directions of torque can be caused by negative sequence of harmonics. These negative impacts are not acceptable for both electric utilities and consumers Therefore, it is very necessary to detect and mitigate these harmonics. There are some traditional techniques used for harmonics mitigations like decreasing non-linear loads for reducing harmonics current, employing filter for absorbing and blocking harmonics current and adjusting frequency response for electric power system [4-10]. Each method has some of its disadvantages. Employing harmonic filter for harmonic mitigation is most commonly used method. But it does not give proper response to the variations in the magnitudes of current harmonics and it does not compensate other components. Therefore, Multireference frame theory is employed for this purpose [5, 11-15].

In this research work a measurement and mitigation method of harmonics based on MRF theory is proposed. A model of DFIG is developed and harmonics are measured by using MRF theory. On the bases of harmonic observer, the simulation model of DFIG for MRF is discussed.

MRF theory is also used for harmonics compensation for a DFIG and Simulation results are represented for various cases.

II. METHODOLOGY

In the proposed method, the MRF theory is used for detection of the harmonics and its compensation for a DFIG model . This design procedure consists of DFIG model,development of MRF method for measurement and compensation of harmonics .

A. DFIG MODEL

The block diagram of DFIG model is shown in Figure 1. This model consists of gear box, wind blades, generator as well as bi-directional inverter.

A gear box has been installed between generator and blades to control the speed of the shaft. To control the DC voltage at bus side, a capacitor has been used to balance the DC voltage.

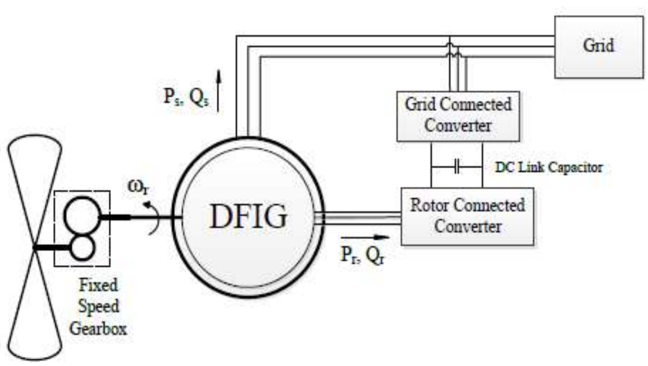

FIGURE 1. DFIG model [6].

The Simulink model of DFIG has been designed in MATLAB as shown in Figure 2. The d-q reference of voltage has been used as an input parameter of the DFIG. Park and inverse Clark transformation has been used to convert constant reference to rotting reference frame.

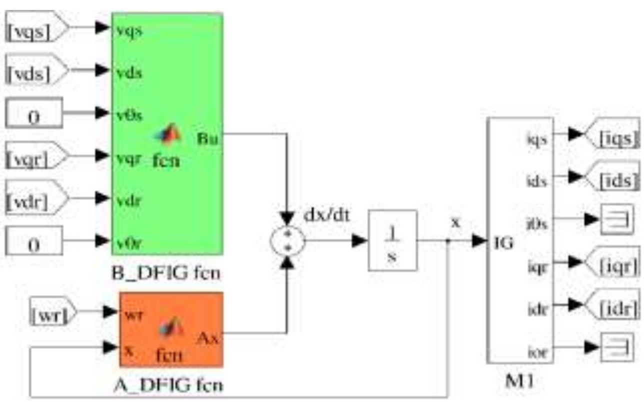

FIGURE 2. DFIG Simulink Model.

A current control loop has been designed to control the d-q components of the rotor current as shown in Figure 3. PI controller has been used to regulate the balance flow of current and further transform it to park and Clark transformation blocks.

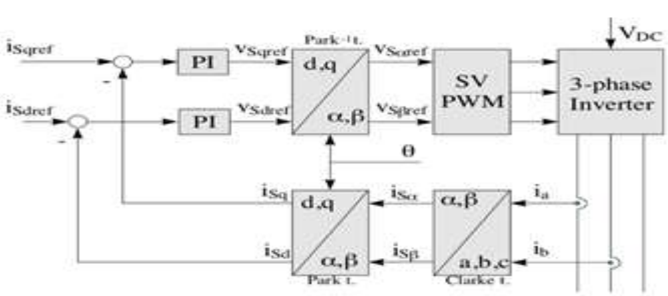

FIGURE 3. VCT for DFIG.

B. MRF HARMONICS OBSERVER

Figure 4 shows the block diagram of harmonics observer used for MRF. In this system MR frames are chosen that vary from base frequency to multiple order frequencies. Current vector has been used as input of this system which passes through multiple tuned transformation phases that is based on matrices to get the current in desired frame of reference.

With the help of this system only relevant component of harmonic current is segregated and fed to the loop used for hormonic calculation.

In order to get the faster response and output in stable mood with no oscillation. The time constant of low pass filter can be adjusted. So, in grid current, this observer can be used for separation of each harmonic component.

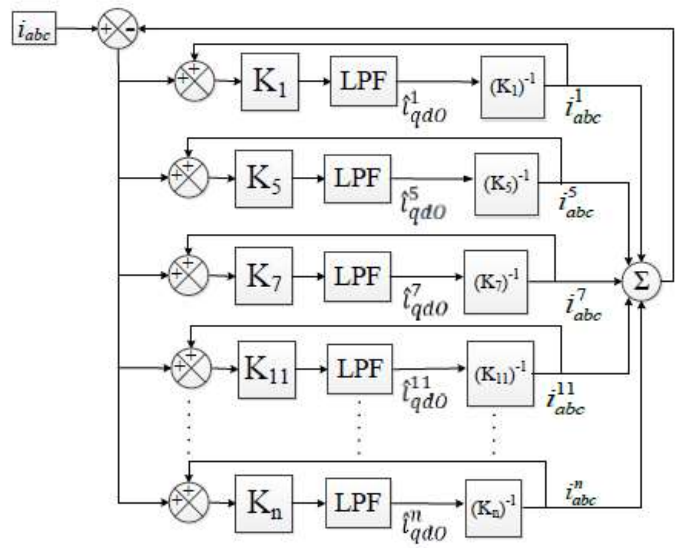

FIGURE 4. Harmonic. observer based on MRF.

- SIMULINK MODEL FOR MEASURMENT OF HARMONICS OF SYSTEM

The subsystem Simulink model for every close loop of MRFHO is shown in Figure 5.

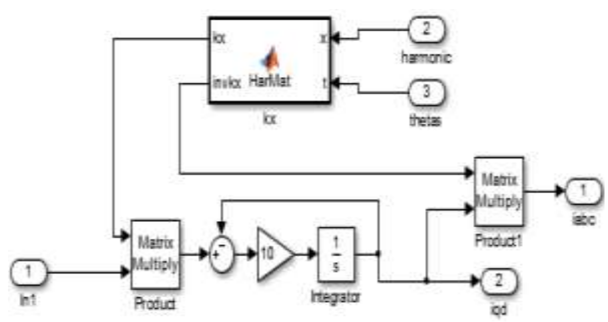

FIGURE 5. Subsystem Simulink model of MRFHO.

It is design for tracking any specific harmonics component. each subsystem is added along with its harmonic specific number. Synchronous angle has been taken as an input of system. Matrices calculations are involved for each subsystem for transformation of reference frame.

The complete model of DFIG machine for measuring harmonics is shown in Figure 6. This model consists of PLL, Generator, MRFHO. First of all, the phase angle has been compared with each other with the help of phase lock loop. A low pas filter has been used in PLL.

After comparison of phase these phase voltages is converted into two rotting reference with the help of park, Clark transformation. A subsystem has been designed for tracking specific harmonic. Every subsystem is based on matrices calculation for transformation of reference frame.

It is designed by using software package of MATLAB Simulink model. In this system power is being supplied to non-linear load. The harmonics of currents caused by this load are measured by using MRFHO.

By using these many subsystems, the MRFHO is simulated for measuring the different modeled harmonics.

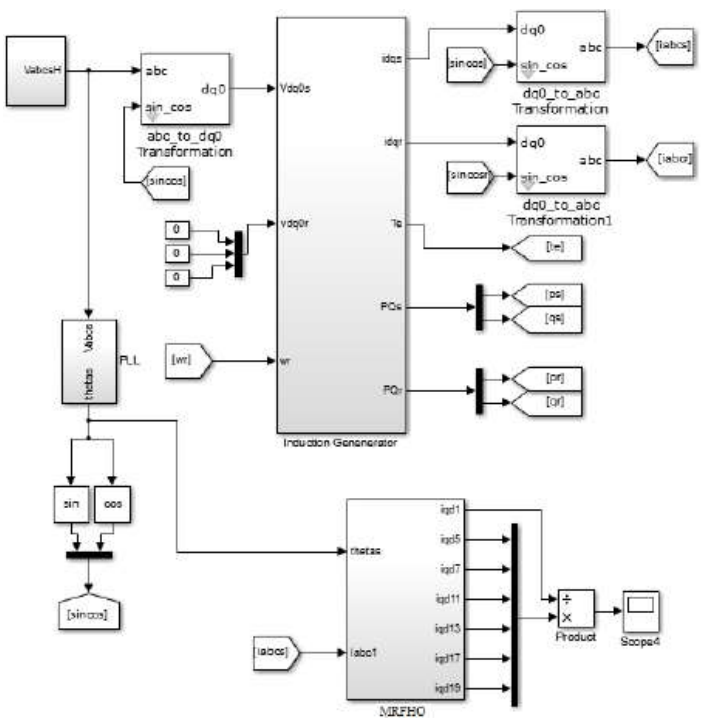

FIGURE 6. Complete Simulink model for measuring Harmonics of system.

C. COMPENSATING SYSTEM FOR DFIG HARMONICS

In order to compensate current harmonics, the order of harmonic might be identified. This order could be done with the help of MRFHO. Block diagram of compensation for harmonics is shown in Figure 7. In this system DFIG is employed. The static part of the DFIG linked with power grid that may contain variable and nonlinear load that can corrupt power of the grid system. The electrical angle of the utility voltage is calculated with the implementation of a PLL and harmonics are injected in the rotor with the help of converter on rotor side.

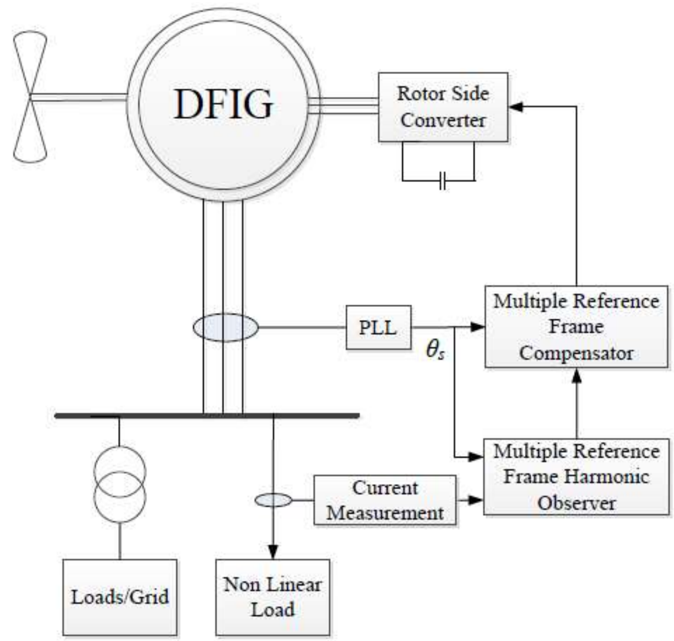

FIGURE 7. Complete Block diagram for measuring Harmonics of system.

The Simulink model used for the compensation of harmonic based on DFIG is shown in Figure 8. With the help of this model some of odd harmonics have been mitigated.

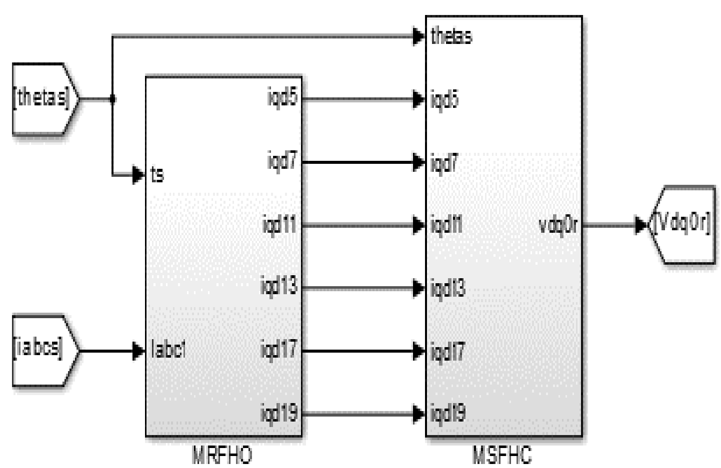

FIGURE 8. Simulink model for harmonic compensation.

III. RESULTS AND DISCUSSION

A. CURRENT HARMONICS MEASURMENTS

3-phase current having harmonics in its complete cycle is shown in the Figure 9. With the help of harmonics observer all odds harmonics has been calculated.

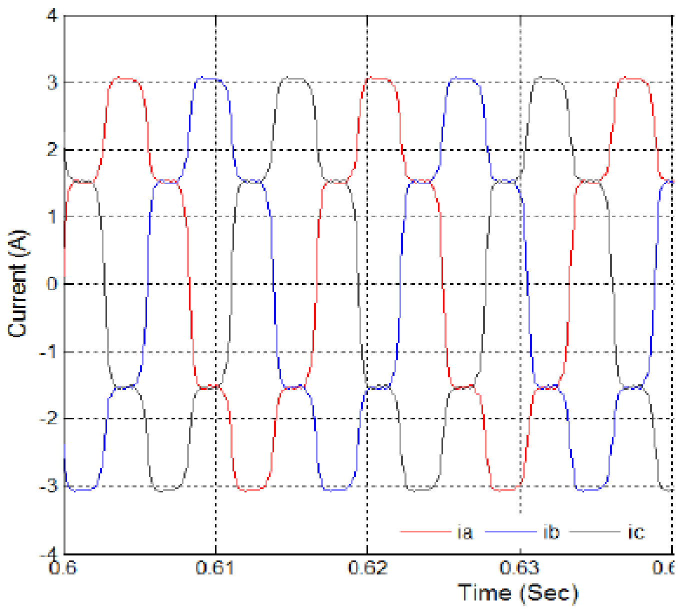

FIGURE 9. Waveform of current without harmonic compensation.

The calculation of all odd harmonics in current wave form is shown in the Figure 10. From this Figure it has been investigated that with increasing the harmonic order, the relative magnitude of the harmonics decrease gradually.

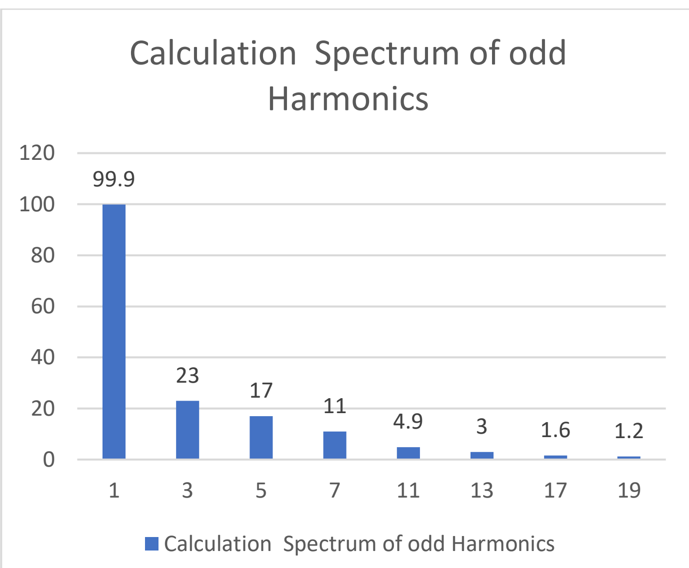

FIGURE 10. Calculation of harmonics spectrum of current.

B. HARMONIC COMPENSATION

Some of Odd Harmonics previously detected are compensated as shown in Figure 11. From this figure it has been analyzed that a balanced current has been achieved with much lesser harmonic components included in complete cycle.

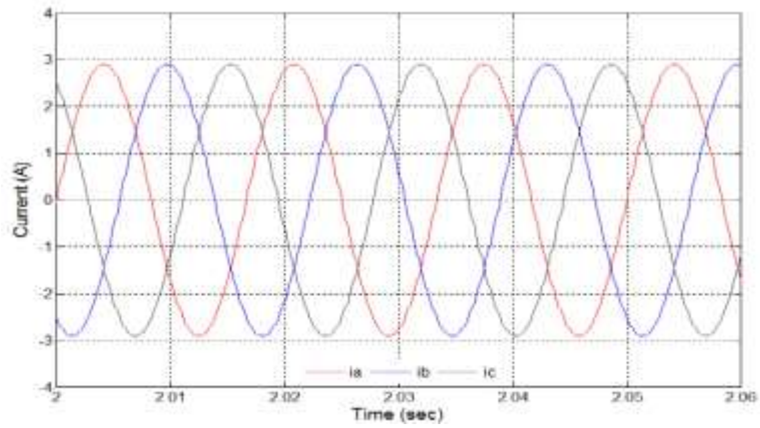

FIGURE 11. Waveform of current after compensation.

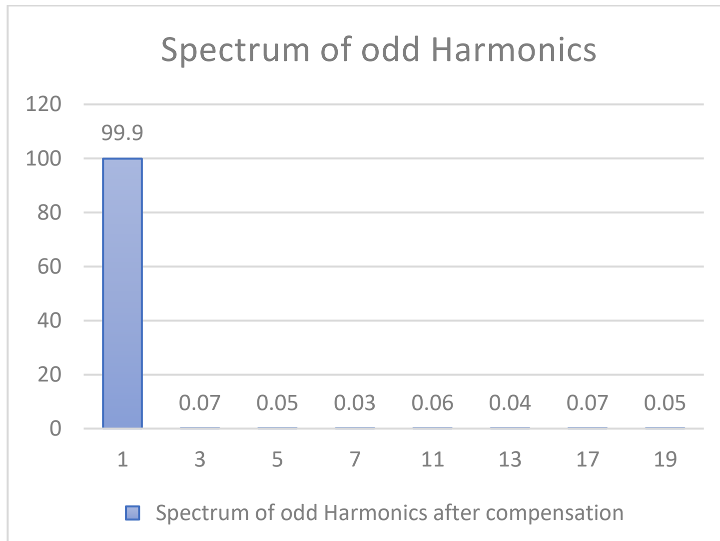

Table 1. Comparison of current harmonics before and after compensation

Order of the Harmonics	% of Harmonics without Compensation	% of Harmonics with Compensation
01	99.99	99.99
05	17	0.05
07	11	0.03
11	4.9	0.06
13	3	0.04
17	1.6	0.07

V. CONCLUSION

In this research work, a technique based on MRF theory has been implemented for the measurement and mitigation of harmonics. This method is very flexible in calculating and measuring the Harmonics in the DFIG based system. MRFHO is implemented for the calculation of harmonics in this system. Simulation and experimental results authenticate the performance of this observer. Harmonic compensation technique based on MRF theory is also implemented for mitigation of harmonics and simulation results illustrate that this method is advantages for reducing harmonics in the current of the system from 23% to 0.78%.

This MRF based theory can also be implemented for solving the other problems of DFIG basing generators used in our power system for the better quality of the power that is prime need of utility and customers. This can also be extended for analyzing the overall effects of injection of Harmonics on rotor and stator windings and design of the machine.

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