Implementation of a Passive Tune Filter to Reduce Harmonics in Single Phase Induction Motor with Varying Load

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Abstract* - Technology has its limitations and problems. Power generation and transmission systems also have some intricacies. Major hindrances involved in achieving efficient power transmission are the effect of harmonics that distorts the required waveform. The paper proposed a methodology that detects the harmonics present in the current drawn by the induction motor by analyzing current waveform through oscilloscope. And then design the harmonic filter using MATLAB programming and implement it on a single phase induction motor for removing the harmonics. The starting and overall performance of motor is important to all the applications. When the motor is started, it draws high starting current. This high current cause's dip in the voltage therefore it is necessary to take into account the remedial measures to remove harmonics in single phase induction motor.

Keywords — **Induction Motor, MATLAB, Filters, Harmonics. Modeling.**

I. Introduction

Induction motor having single phase is a single-phase motor. In single-phase induction motors the stator windings consist of one phase, so there is no rotation of magnetic fields. There is no starting torque in a motor because of the absence of rotating magnetic field of stator. Single phase induction motors are a common part of home and industrial appliances which cause the phenomenon of harmonics in the system they are integrated with. Other major sources include non linear loads like a diode, saturated transformers and more importantly large rectifiers and Adjustable Speed Drives (ASD's) [1].

Power systems are designed to operate at frequencies of 50 or 60 Hz; but, some types of electronic loads produce currents and voltages with frequencies which are integer multiples of the 50 or 60 Hz. These higher frequencies are known as power system harmonics. Today, harmonics are mostly created by electronic loads such as adjustable-speed drives (ASD) and inverters. However due to many advantages like efficiency and controllability, almost all the power equipments from low voltage appliances to high-voltage converters contain power electronic loads. Hence due to more use of electronic loads, power system harmonics is the big problem [2].

Although the starting current of single phase induction motors also causes performance and efficiency loss but this problem has been handled effectively in past researches, one of which suggests the use of classical LC circuit integrated with the capacitor run induction motor to reduce starting high current and thus improving the efficiency [3]. Disturbance in the power system is often caused by non-linear loads. The non-linear load draws non-sinusoidal periodic current even when sinusoidal voltage is applied to these loads. The current waveform becomes very complex due to the type of load and its interaction with other components of the system. . As an example, consider the supply voltage and current of a three phase variable Speed drives [4]. There are a number of ways to overcome the problems of power quality and Harmonics.

Reduce mutual coupling between circuits by shielding. [5]. Harmonics can be reduced and eliminated through transformer connections. A separate delta connected tertiary winding is usually wound on high power transformers to provide a path for circulating triple harmonics to flow. However, losses increase because of circulating current in the delta connection [6]. Generator voltage harmonics can be reduced by the use of distributed windings [6]. Install power harmonics filters. The purpose for power harmonic filters installed at the connection of power electronic equipment to the power system is to bypass the harmonic current generated by the equipment from entering the power system [6]. Harmonic injection can be used. For power systems serving non-linear loads, a power electronic converter generates harmonic current demanded by the loads. That eliminates the need for such current to flow in the power system [6]. Install the active filter; an active harmonic filter boosts voltage throughout each half AC cycle, providing the load with a regular voltage waveform [7]. This paper implemented a modern technique that is to design a filter that install in series or in shunt with the induction motor to reduce harmonics during starting of the motor as well as at fully loaded condition. Four different approaches are implemented to overcome harmonics induced from the motor and finally concluded a technique that suits the best above all.

II. Proposed Methodology

This paper proposed a filter design to reduce the harmonics generated by the single phase induction motor with varying load. Fig.1 describes the complete flow chart of the proposed system. How the frequency components of the input signal accompanied with harmonics are analyzed using Matlab tool. After analyzing the signal behavior, different approaches have been made to design a filter

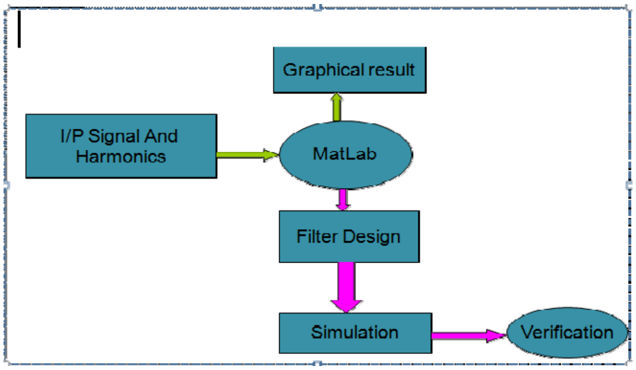

Fig 1: Flow chart of the Proposed System.

using Matlab Simulink. Each method has been verified practically and concluded the results.

III. Experimental Setup

The detailed description of the experimental setup is stated in this section. Different approaches that are used during the implementation of the required filter that can reduce the harmonics up to the optimum level are thoroughly discussed.

Induction motor used for the analyzing the distorted signal during the hardware setup is shown in Fig 2. Mechanical load on the motor is applied coupled with the rotor of the machine. It applies variable mechanical braking load. Load is varied by using its variable braking knob. Specifications of the motor are stated in table 1.

A. Approach 1

The first approach implemented for the passive filter in comprises of a resistor, inductor and two capacitors making an RLC circuit. Fig. 3 represents the complete circuit diagram of the filter.

Fig 2: Motor with mechanical load.

Table 1: Motor Specification

Motor Rating	
Rated speed	1440rpm
Rated voltage	220-240
Full load current	2 A
Frequency	1 ~ 50 Hz

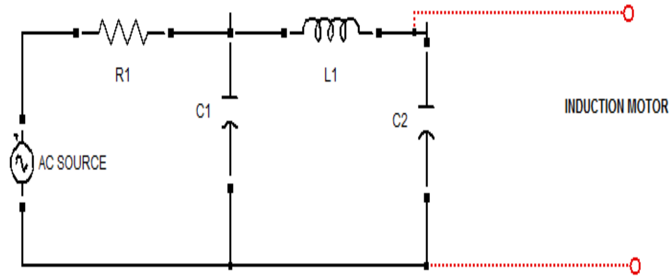

Fig 3: Passive Filter Approach 1.

Fig 4: Experimental Setup of Approach 1

Implementing the above circuitry and analyzing the results on oscilloscope as shown in Fig 4 found that as stated about the passive filter that it can remove the higher frequency components and pass the required frequency. The above filter does not give proper result. The output wave form is distorted. This approach has 1.2A over all current rating however only 0.4A is passing through motor which is not sufficient for motor. So we switched on different techniques for filtrations purpose.

B. Approach 2

In the second approach, little alteration is made in a passive filter of approach 1. One Inductor is removed and the overall design is changed as shown in Fig 5. Implementing the above filter approach practically as shown in Fig. 6, founded that the designed passive filter gives result which has distorted output wave form with 0.95A overall current and 0.9A is passing through motor which is better than the previous filter made.

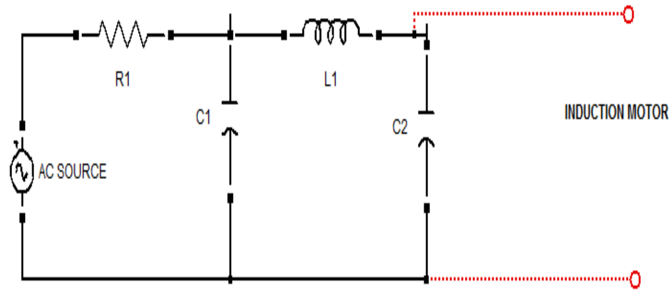

Fig 5: Passive Filter Approach 2.

Fig 6: Experimental Setup of Approach 2.

C. Approach 3

In 3rd approach, only the series LC filter is used to remove the harmonics. The circuit was tuned on 50 Hz frequency following Fig. 7 describe that filter circuitry and Fig. 8 shows its complete practically implemented diagram. Although this filter have good result in form of sinusoidal wave form but the main disadvantage of this fitter it carries high current. This is dangerous for motor. So we move to another filter.

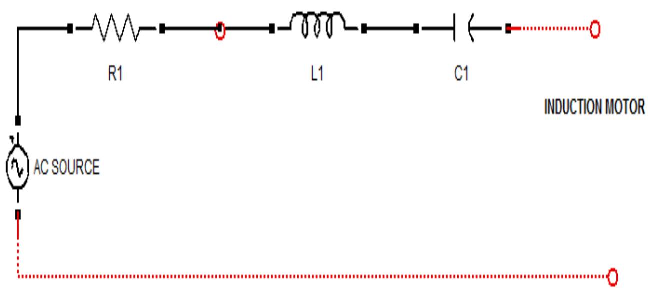

Fig 7: LC Filter Approach

Fig 8: Experimental Setup of LC Approach.

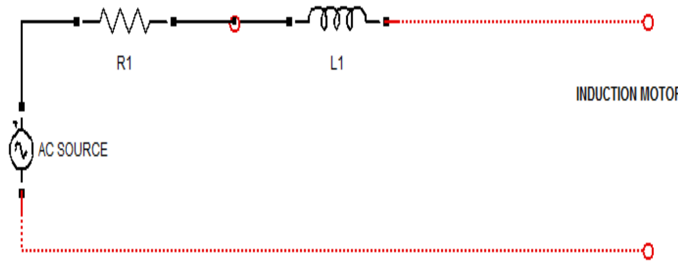

Fig 9: Series Inductor Approach

Fig 10: Experimental Setup of Approach 4

D. Approach 4

In this approach we use only single inductor in series with the resistor as shown in Fig. 9. Experimental setup of this approach is shown in Fig. 10.

The main problem in this configuration is a large voltage drops across inductor which is about 80 volts. So, heavy load cannot be used across motor. As the voltage across the motor is 150 volts.

E. Final Approach

Finally, a passive filter approach is designed and implemented as shown in Fig. 11. L1 and C1 are in parallel with L2 and C2.

The Fig. 12 describes that after filtrations of both 7th and 5th harmonics, distorted signal change in to pure sinusoidal wave form. And there is no extra current with respect to the safety of motor so this is the proposed filter for induction motor.

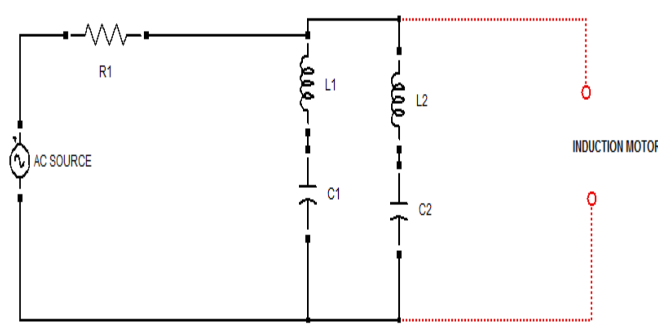

Fig 11: Passive Filter Approach

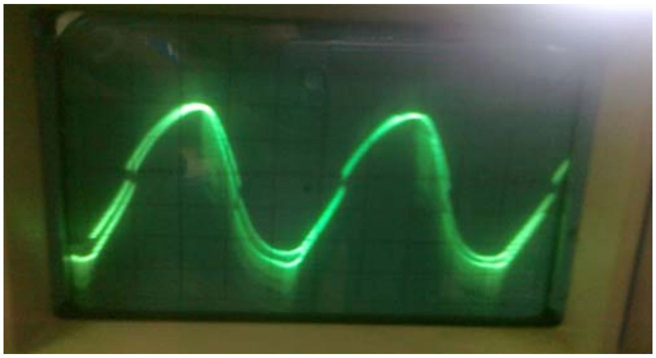

Fig 12: Waveforem after removing 5th and 7th Harmonics

IV. Fourier Analysis

If a signal is combination of different frequencies with different amplitude then frequency cannot be observed using time domain analysis for this frequency domain is used that represent the Fourier transform of the required signal. The Fig. 13 is describing about the frequency spectrum and amplitude of distorted signal. From the above Fig. it is clear that the fundamental frequency 50 Hz have the maximum amplitude. The 3rd harmonic frequency 150Hz have less amplitude then 50Hz signal, as the harmonic order increases the amplitude of spectrum is decreased.

A. Parallel Passive Filter Implementation in Matlab

After analyzing harmonics, filter is designed that can overcome the harmonics and can provide a pure sinusoidal waveform during starting and on load condition of the motor. Fig. below shows the distorted waveform on which the filter technique is to be implemented. Fig. 15 represents the technique that is reducing the 5th and 7th Harmonics. Designing the above filter in MATLAB Simulink whose function is to ground the distorted current wave form of different frequencies and provide pure sign wave to induction motor for maximum efficiency, following output is obtained shown in the Fig. 16.

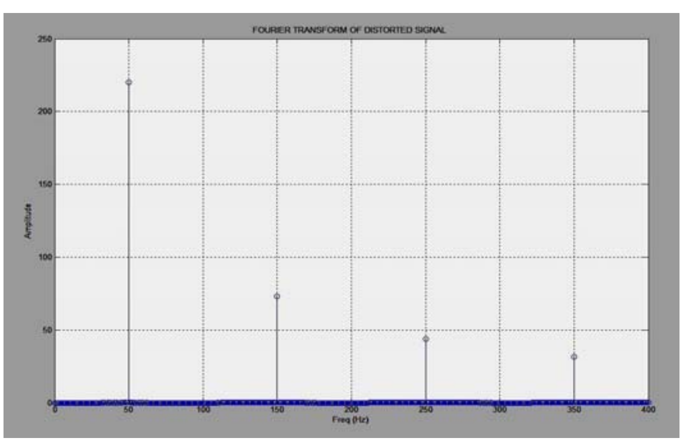

Fig 13: Fast Fourier Transform of Distorted Signals

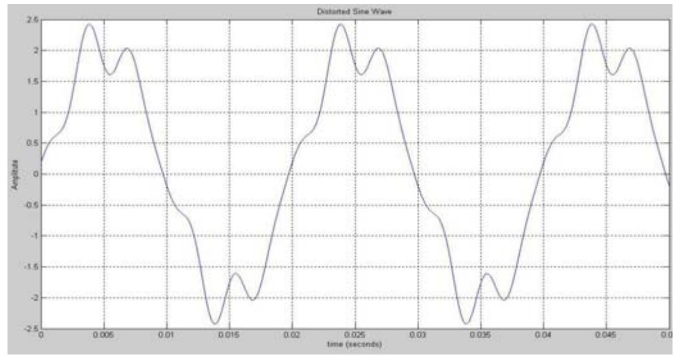

Fig14: Distorted signal

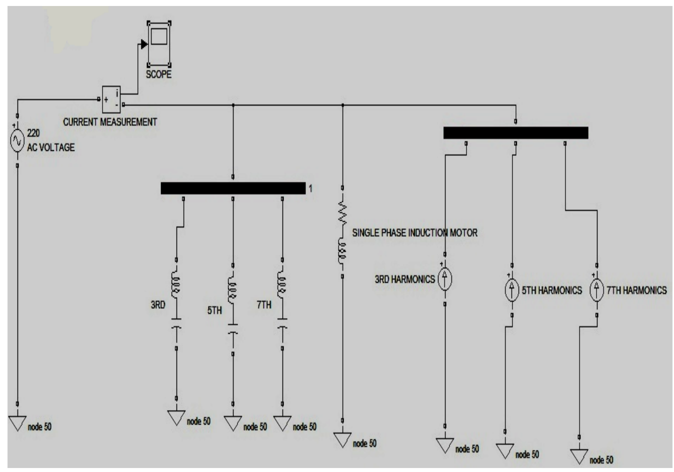

Fig 15: Parallel Passive Filter

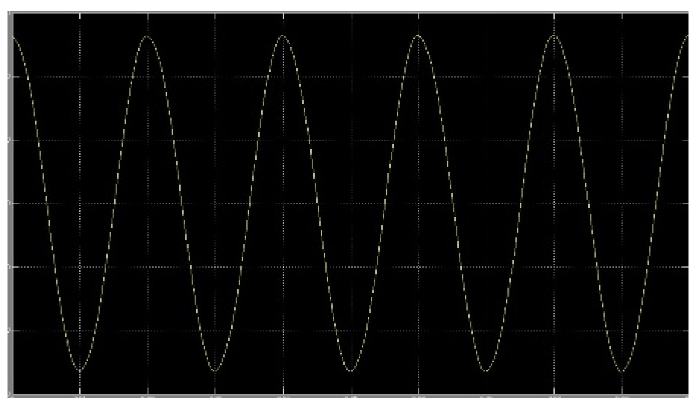

Fig 16: Output of the filter

V. RESULT ANALYSIS

This section shows the result obtained practically on various stages of designing of different types of filters and the problems that are faced during designing of a filter that can reduce the harmonics up to the maximum level. Table 2 shows the results obtained.

Table II
RESULT ANALYSIS

Approach	Resistor	Inductor		Capacitor		Issues
	R1	L1	L2	C1	C2	
First	1Ω	125mH	---	7.5μF	7.5μF	Distorted waveform, 1.4 Overall current and 0.2 Passing through Motor
Second	1Ω	125mH	---	2.2μF	2.2μF	Distorted wave 0.95 overall current and 0.9 passing through motor
Third	1Ω	125mH	---	2.2μF	---	High current which is dangerous for motor.
Fourth	1Ω	125mH	---	---	---	Large voltage across inductor
Final	1Ω	125mH	125mH	1.1μF	1.75μF	Pure Sinusoid

VI. Conclusion

The design of such kind of system that can be able to reduce the harmonics in the induction motor is presented in this paper. The best way to overcome the problem is suggested to be using the harmonic filters. Harmonic filters are which will not only suppress harmonics but also supplies the reactive power for the improvement of power factor. MATLAB programming makes it easier to design filter for any input or desired data without requiring any laborious and tedious calculations. Four different filters are designed and compared to get the best filter out of them. In addition to above all, suggested that for providing a more convenient and suitable control settings to a person it is necessary to provide a more user friendly Graphical user Interface.

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