Design of DC Link Filter and Inverter Output Filter for Induction Motor Drive System.

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ABSTRACT: *This paper presents Design of Dc link filter and Inverter output filter for induction motor drive system. In recent years, harmonics are considered as one of the most essential problems in electrical power systems, Even though, this new highly efficient electronic technology provides improved product quality with increased productivity by the use of smaller and lighter electrical components but they are the sources of harmonics the perfect sinusoidal voltage and current waveform are very much distorted. To solve this problem, a simple and practical approach to reduce harmonics current in 3-phase system is proposed. The using of LC filter and inverter output filter in three-phase system will reduce the harmonic problem in the system. This LC filter is depending on value of capacitor and inductor. It will reduce harmonics in the system. In the proposed scheme, dsPIC30F4011 controller is used to produce signals. An induction motor of 1.1KW, 1440RPM, 415V, 2.6A rating are used as load for testing the developed hardware. Textronics TDS2024B storage oscilloscope is used to store the gate pulses and waveforms.*

Keywords—*Bridges, DC link filter, IGBTs, Induction motor, LCR filter.*

I.   INTRODUCTION

Induction motors are widely used in high performance drive systems, because of its advantages like high efficiency, very simple in construction and good power factor. Variable speed operations can be achieved by induction motor. The conventional approach of motor control is to first convert the line voltage (AC) into DC. DC is again converted to single/three phase AC as per load requirements. The output voltage, frequency or both of inverter can be controlled by the application of power electronics and microcontroller/ICs.Various synthesis methods produce different harmonic spectra. Much is studied and talked about harmonics and its effects towards input/supply side. As far as analysis of levels of various harmonic orders and dV/dt at different rpm-load combination is considered, only in some datasheets of the manufacturers the effect of filter unit is given at the rated specifications of the motor.

To solve this problem, a simple and practical approach to reduce harmonics current in three phase system is proposed. The using of the DC link filter in the rectifier side of the three phase will reduce the higher order harmonic problems and the use of the filter in the inverter output side of the three phase will reduce the harmonics which are present at the inverter. The speed control is undertaken by using variable frequency method. The frequency is varied by controlling the switching (on/off) of power IGBTs (of inverter).

The developed hardware is tested on a 3-phase, 415V, 50Hz Induction motor. According to the requirement, a software program is written and is fed to the digital signal controller **(dsPIC30F4011)** for the necessary action. The controller circuit essentially takes the output frequency of the inverter, the set speed and actual speed of the motor into account. Depending upon the difference between the set speed and actual speed, the microcontroller decides the frequency of gate pulse of IGBTs. The output to the motor is given through filter circuit. The various graphs/waveforms and harmonic orders are analyzed and studied on **Digital Storage Oscilloscope (DSO).** The results are studied in two parts. In the first part the closed loop control of the motor is studied and in the second part the harmonic analysis is done. A gross comparative study, with and without output filter, is made.

II. BLOCK DIAGRAM AND ITS EXPLANATION

1. System overview

The block diagram of the proposed Design of Dc link filter and Inverter output filter for induction motor drive system is shown in fig 1. It has Inverter, Rectifier, filters, Gate drive unit, Control unit.

It has 3phase full bridge rectifier, DC link filter, 3phase full bridge inverter, LCR filter, control circuit. In the proposed work, the 3phase full bridge rectifier consists of 6-6A-100L. Each leg having two diode sets (upper and lower).Each set has two diodes connected in parallel to increase/double current rating. The output of

the rectifier is filtered by DC link filter of 1000μF inductor and two 450V capacitors. A DC link filter is required to smooth out the ripple on the DC bus in order to run the inverter bridge.

The 3phase full bridge inverter has 6-FGA25N120ANTD-IGBT's switches. The inverter is followed by Gate drive unit and a control unit. The primary function of the gate drive circuit is to convert logic level control signals into the appropriate voltage and current for efficient, reliable, switching of the IGBT module. In this work an opto-coupler TLP250 is used to isolate the gate drive circuit and the IGBT based inverter circuit. The opto-coupler consists of an infrared light-emitting Diode and a silicon phototransistor. The input signal is applied to the IRLED and the output is taken from the phototransistor.

After the inverter section there is another LCR filter being placed so that the remaining harmonics at the inverter side can also be reduce and the approximate sinusoidal waveform can be obtained at the output.The output of 3phase full bridge rectifier with DC link filter, 3phase full bridge inverter is applied to the three phase induction motor. A digital signal controller (dsPIC30F4011) is used to implement the core of the control function, which simplifies the hardware setup.
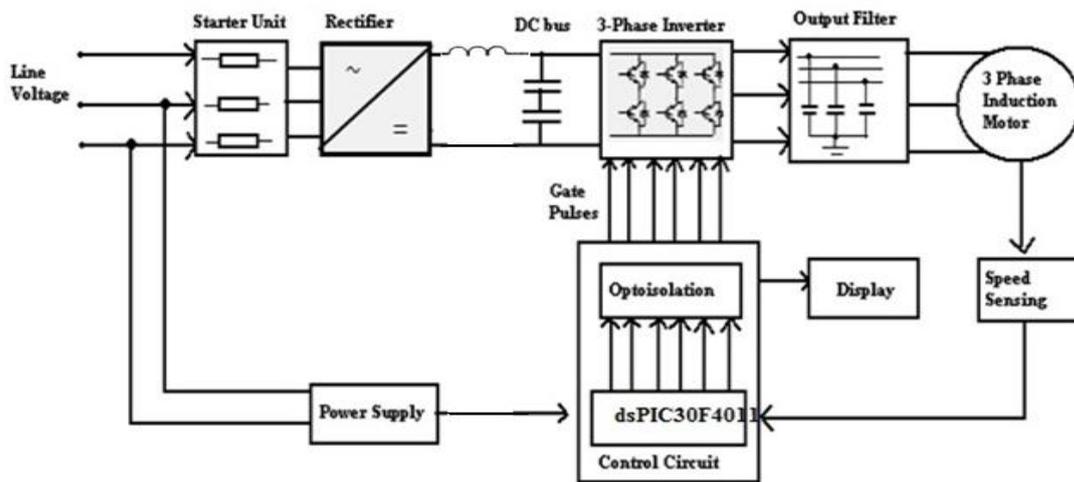
Fig1. Block diagram of the proposed system

2. Power circuit design

The power circuit designed contains full bridge rectifier with DC Link filter, full bridge inverter assembly and LCR filter assembly. At the start of the motor it experiences a very high current and the motor may not run at the rated speed. An electromagnetic relay is used in the proposed scheme. Starting current of the induction motor is six times that of the rated current for a duration of 4 Seconds. To limit this heavy current flow, two wire wound resistances of 50Ω, 10W each are connected in parallel to the input supply. A single pole change over relay is used to insert these wire wound resistors for a period of 4secs and then the relay bypasses these resistors for the rest of the operation.

Three phase 415V, 50Hz AC supply is applied to the full bridge rectifier via starter assembly. This full bridge rectifier converts three phase AC input into DC which is then passed to the DC link filter by two electrolytic capacitors and an inductor. The pure DC supply is applied to the full bridge inverter which is made up of six IGBT switches. This DC output is been given as input to another filter unit. The 3-phase induction motor is connected to full bridge rectifier with DC link filter, full bridge inverter, RCL filter and control circuit. The DC Link filter and the RCL filter is shown in figure 2.1 & 2.2. The DC link filter is used to smooth out the ripple on the DC bus in order to run the inverter bridge. Primarily, the DC link filter consists of a large capacitor bank. Often an inductor and capacitor is used. The inductor when used, helps buffer the capacitor bank from the AC line and serves to reduce the higher order harmonics. Even after the DC link filter is been used the output of the inverter unit is of non-sinusoidal. The RCL filter is the conventional approach used to filter the output from inverters. In this present work, a passive filter is used at the inverter output side also to reduce the effect of the harmonics.
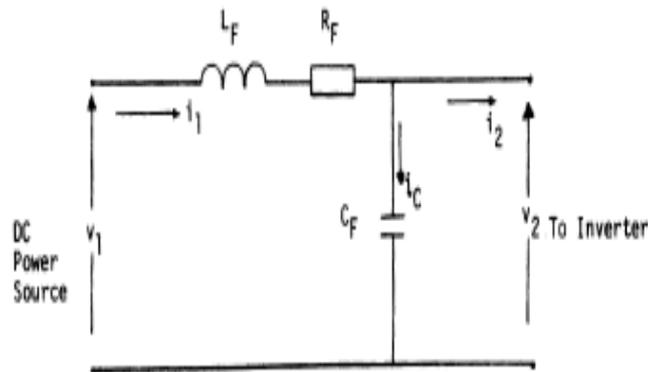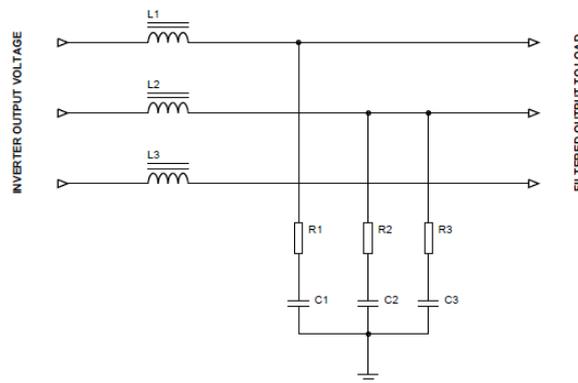
Fig2.1 Equivalent circuit of DC link filter

Fig2.2 RCL inverter output filter

3 .Control circuit

The control circuit of the proposed scheme consists of a Digital signal Controller dsPIC30F2010.A Digital Signal Controller (DSC) is a single-chip, embedded controller that seamlessly integrates the control attributes of a Microcontroller (MCU) with the computation and throughput capabilities of a Digital Signal Processor (DSP) in a single core. The dsPIC DSC has the "heart" of a 16-bit MCU with robust peripherals and fast interrupt handling capability and the "brain" of a DSP that manages high computation activities, creating the optimum single-chip solution for embedded system designs. The dsPIC30F devices contain extensive Digital Signal Processor (DSP)   functionality within high-performance 16-bit microcontroller (MCU) architecture. It also consists of six opto-coupler for isolating the control and power circuits. In this work an opto-coupler TLP250 is used to isolate the gate drive circuit and the IGBT-based power circuit Six IGBTs of the power circuit are controlled by the PWM signals generated by the control circuit.

## III.   EXPERIMENTAL SETUP AND IT RESULTS

The Design of Dc link filter and Inverter output filter for induction motor drive system is done successfully and the developed hardware is tested with load. The proposed control system is implemented by a DSC (dsPIC30F4011) based PWM inverter. C language is used to develop the program. The device is programmed using MPLAB Integrated Development Environment (IDE) tool. It is a free, integrated toolset for the development of embedded applications employing Microchip's PIC and dsPIC controllers. For execution of C-code, MPLAB compiler is used. In this work, I have used 415V, 50Hz, 3-Ph, 1.5 HP Induction motor.

The hardware set is developed and tested in power electronics laboratory and the photograph of complete setup is shown in fig 5. The test is carried out on induction motor for different loads and set speed. For different loads and set speed, current drawn by the motor and frequency of output voltage across all lines are noted and are tabulated.

In the complete experiment the oscilloscope used is Tektronix TDS2024B Digital Storage Oscilloscope (DSO) to store gate pulses and voltage waveforms. The speed of the induction motor is 1440 RPM, At particular RPM, load is varied from 1KG to 3KG and corresponding voltages and currents are noted.

### A. Experimental results analysisof speed control

Various readings for various speed-load combinations are taken. Table 1, 2, 3 shows the reading for various loads, (measured in terms of weight depicted by the spring balance-pulley system) for the RPMs 1350, 1400, 1440 respectively. Fig 3.1, 3.2, 3.3 shows the gate pulses for the above RPMs
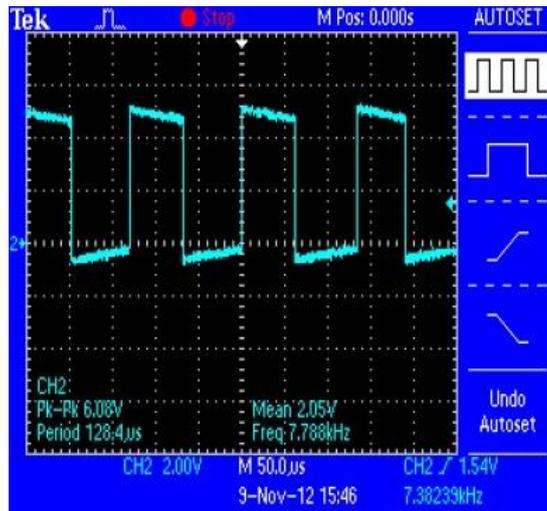
Fig 3.1: Gate pulse at 1000gm for 1350rpm
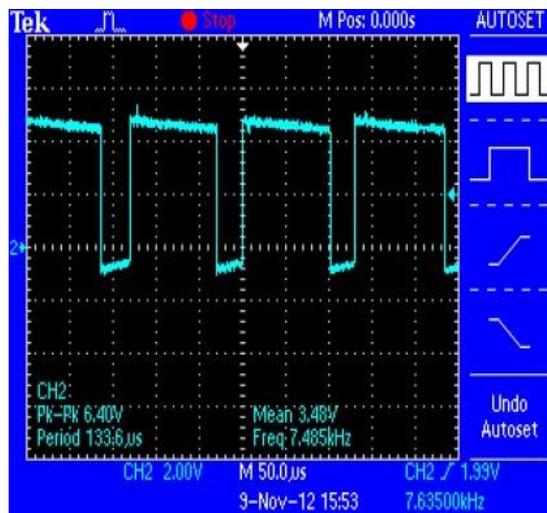
Fig 3.2: Gate pulse at 1000gm for 1400rpm
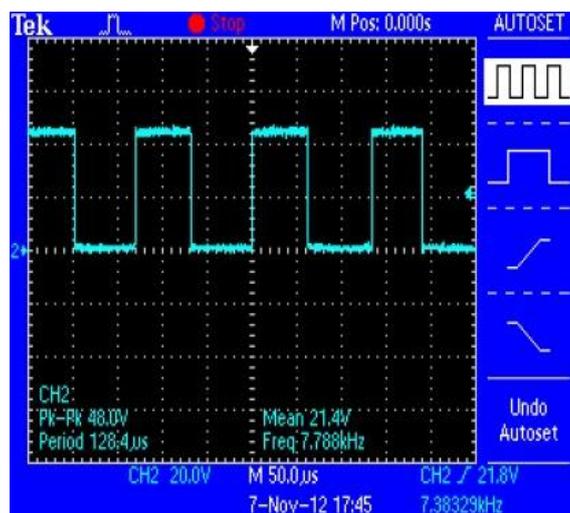
Fig 3.3: Gate pulse at 1000gm for 1440rpm

Table 1 Results for load v/s speed as 1350rpm

Sl no.	Load in gms	Actual rpm	Frequency of output voltage	Current (Amp)	Output voltage (volts)
1	500	1340	46.41	0.42	140
2	1000	1360	46.85	0.49	170
3	2000	1380	46.54	0.57	175
4	3000	1360	46.14	0.53	180

Table 2 Results for load v/s speed as 1400rpm

Sl no.	Load in gms	Actual rpm	Frequency of output voltage	Current (Amp)	Output voltage (volts)
1	500	1390	42.74	0.43	170
2	1000	1300	42.97	0.41	170
3	2000	1410	43.14	0.46	270
4	3000	1380	43.51	0.58	300

Table 3: Results for load v/s speed as 1440rpm

Sl no.	Load in gms	Actual rpm	Frequency of output voltage	Current (Amp)	Output voltage (volts)
1	500	1430	41.32	0.45	130
2	1000	1440	41.92	0.51	140
3	1500	1460	43.42	0.55	180
4	2000	1450	43.86	0.53	210

B. Experimental results analysis of Harmonics with and without filters

In the present work the harmonics contents predominantly present in the stator voltage are studied and attempt is made to reduce them using filter units. This contributes to prolong the life of motor and reduce torque pulsations. The figures 4.1, 4.2, 4.3 shows the waveforms without filter and with filter at different loads and set speed.
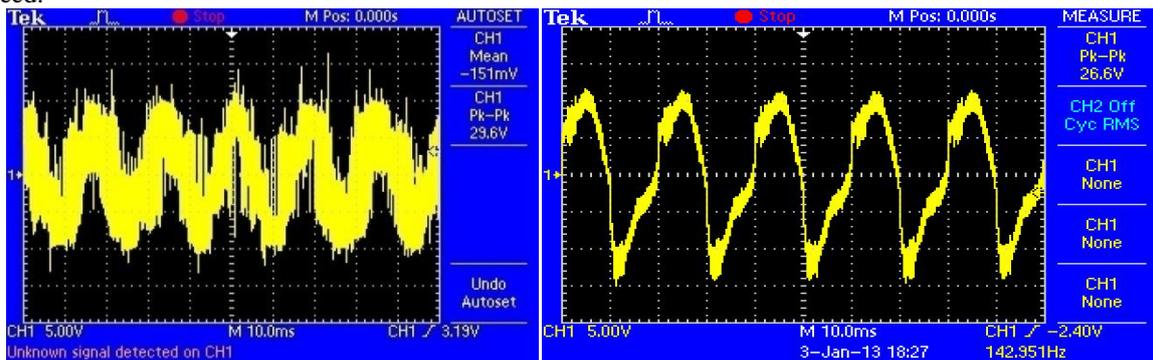
Fig 4.1: Inverter output voltage waveforms at 500gm (with and without filter) for 1350rpm
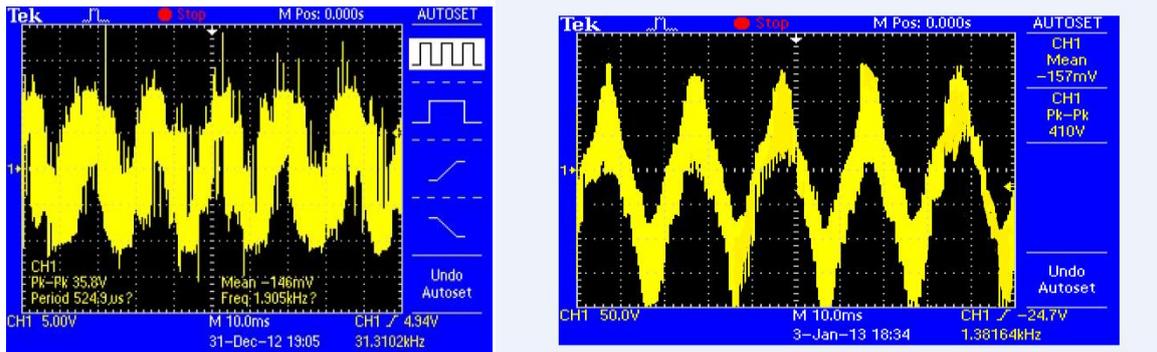
Fig 4.2: Inverter output voltage waveforms at 2kg(with and without filter) for 1350rpm
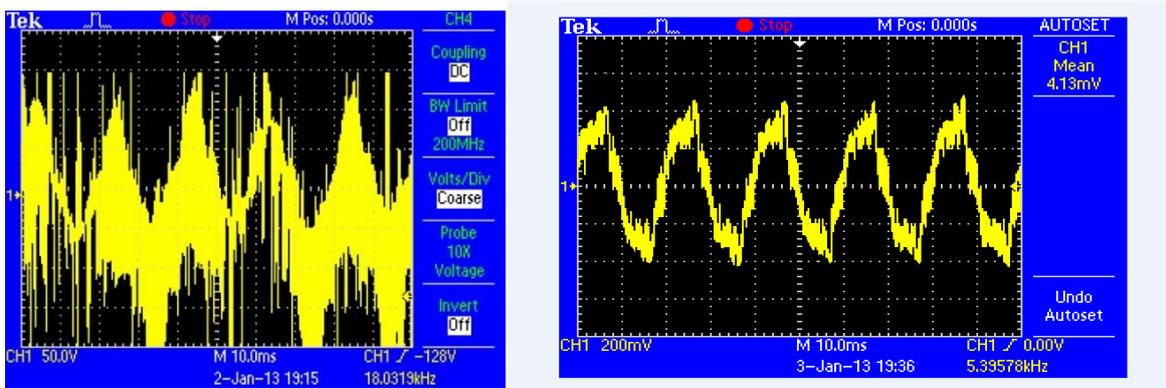

Fig 4.3: Inverter output voltage waveforms at 500gm (with and without filter) for 1400rpm
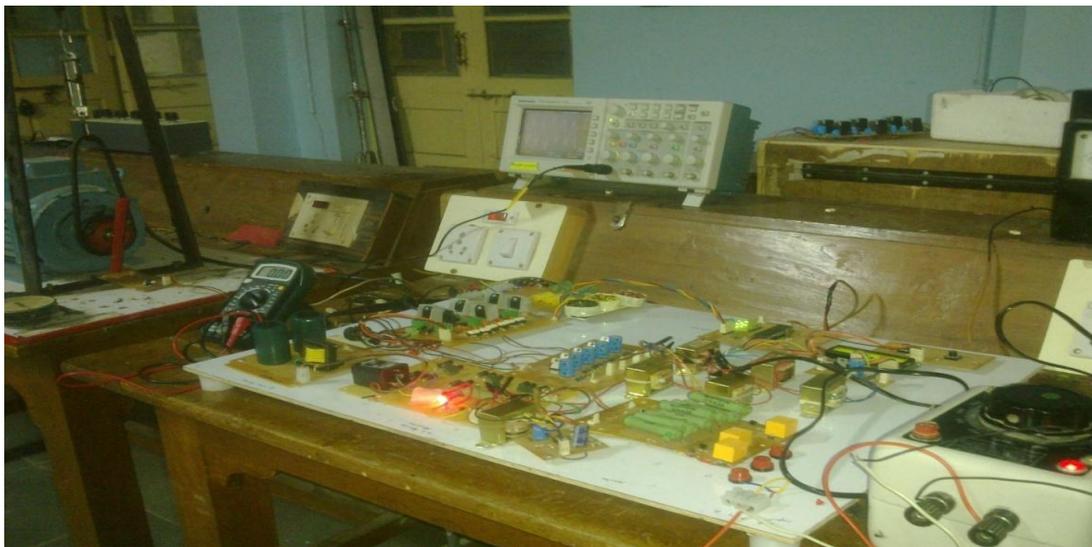

Fig 5 Photograph of the complete designed system

IV. CONCLUSION

In this paper, Design of DC link filter and inverter output filter for three phase induction motor drive system has been presented. The developed hardware setup is tested on a three phase 1.5hp, 415V, 50Hz induction motor with loading in power electronics laboratory.

The harmonic contents at the output were studied on the storage oscilloscope. We found that the designed filters effectively reduced the harmonic distortions.

From the experimental setup and results chapter it is observed that by the use of the designed filter at the rectifier and at the output of the inverter, almost a pure sinusoidal supply is given to the motor drive system, with this the operation of closed loop control system becomes very smooth and the torque pulsation will be reduced to the maximum extent. With this we can say that efficiency of the overall system is increased.

Advantages of the Design of DC link filter and inverter output filter for three phase induction motor drive system are:

> Reduction in harmonics, improved life of the motor, high efficiency, high power factor.

There are various application areas for harmonic filters, the most important being: Adjustable speed drives, Computer Equipments, Welders and Battery charges.

APPENDIX

The following defines the nomenclature and system parameters used in this paper :

A. Molar parameters and nomenclature: 50Hz, 415V, 1.5hp, 3-phase, 4-pole induction machine.

B. Inverter parameters : Vin : lnput voltage 415V

CT1, CT2 : DC bus capacitors 1000μf , 450V each

Q1,Q2, Q3, Q4, Q5, Q6: IGBTs **FGA25N120ANTD** 1200V, 25A

REFERENCES

[1]. K.S.Rajashekara collectively published a paper titled "DC Link Filter Design Considerations in Three-Phase Voltage Source Inverter-Fed Induction Motor Drive System" In IEEE transactions on industrial electronics, vol. 51,no. 3, june 2004

[2]. Najwa Mahamad Collectively published a paper titled "Application of LC Filter in Harmonics Reduction" National Power & Energy Conference (PECoo) 2004 Proceedings, Kuala Lumpur, Malaysia.

[3]. A manual from Rockwell Automation Mequon,WI "Straight Talk about PMW AC Drive Harmonic Problems and solutions".

BOOKS:

[1]. Rashid M.H, "Power Electronics-Circuits, Devices and Applications", third edition Printice HallIndia,2001.

[2]. Bimal K.Bose, 2002, "Modern Power Electronics and AC Drives", Prentice-Hall India.