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IGBT based Induction Motor Soft Starter

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ABSTRACT: *Three-phase induction motor of ratings beyond 50 kW take very large currents and low power factor while being started directly from a 3-phase supply. In order to mitigate the adverse effects of starting torque transients and high inrush currents in induction motors, a popular method is to use electronically controlled soft-starting voltages utilizing IGBT's. Normally soft-starters are used for avoiding this problem and to achieve smooth starting of large capacity induction motors. Soft starters use ac voltage controllers to start the induction motor and to adjust its speed. The performance of a voltage-controlled large induction motor soft starter has been improved, resulting in nearly perfect current and torque profiles. Soft starters are used as induction motor controllers in compressors, blowers, fans, pumps, mixers, crushers and grinders, and many other applications. Starting torque pulsations are eliminated by triggering back-to-back-connected IGBT at proper points on the first supply voltage cycle. The soft starter is connected in motor drive during the starting condition only and once the motor get its rated speed then the soft starter is disconnected from the main motor system so that the motor get protected. For analysis of the various waveforms Digital Storage Oscilloscope Textronix TDS2024B is used.*

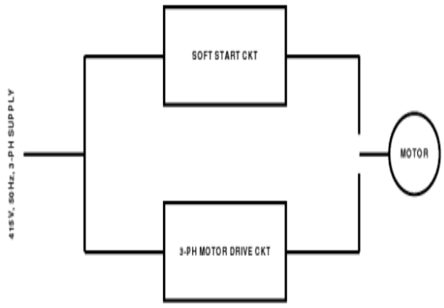
Keywords*- AC voltage controller, dspic30F2010, Induction motor, soft starter***.**

I. INTRODUCTION

Like induction motor (IM) variable speed drives, soft starters are also essential components in every modern IM drives and automation systems [1]. In almost every application the squirrel cage Induction Motor is used. Whenever a squirrel-cage induction motor is started, the electrical system experiences a current surge, and the mechanical system experiences a torque surge. With line voltage applied to the motor, the current can be anywhere between four to ten times the motor full-load current. The magnitude of the torque (or turning force) that the driven equipment will be in excess of 200% of the motor full-load torque. These current and torque surges can be reduced substantially by reducing the voltage supplied to the motor during starting. AC voltage-controller-based soft starters offer many advantages over conventional starters such as the following. Smooth acceleration, which reduces stress on the mechanical drive system due to high starting torque hence increases the life and reliability of belts, gear boxes, chain drives, motor bearings, and shafts.

Smooth acceleration reduces also stress on the electrical supply due to high starting currents meeting utility requirements for reduced voltage starting and eliminating voltage dip and brown out conditions. It reduces also the shock on the driven load due to high starting torque that can cause a jolt on the conveyor that damages products, or pump cavitations and water hammer in pipes. Thus, a fully adjustable acceleration (ramp time) and starting torque for optimal starting performance, provides enough torque to accelerate the load while minimizing both mechanical and electrical shock to the system. Energy savings at lightly loaded conditions.

Energy savings by voltage control is achieved by reducing the applied voltage if the load torque requirement can be met with less than rated flux. This way, core loss and stator copper losses can be reduced [2]. In this work an attempt is made to develop a soft starter for a three phase Induction Motor drive. The soft starter uses two anti parallel connected switches in each phase. The IGBT"s are used as the switches in this work because of their higher power rating and high efficiency. The Fig. 1 shows the block diagram of the entire system. In the Fig.1 the motor is connected to the soft starter at the starting and once the motor get its rated speed then the soft starter is disconnected and the motor drive system take the control over the motor. By using soft starter the controlled voltage is applied at the motor input so the motor is protected and life of motor increases.



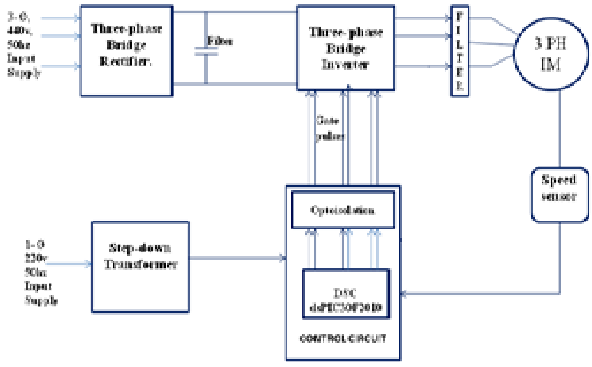


Fig 1: Block diagram of complete system

Fig 2: Block diagram of motor drive system

The Fig.2 shows the block diagram of motor drive system. The motor drive system consists of a rectifier, inverter, controller and the filter units. In the inverter the IGBT‟s are used as the switches. To operate these switches the gate pulses should be given. The control circuit gives the required gate pulses for the inverter switches, the dsPIC30F2010 is used as the controller. The motor drive system uses V/f control method.

The Fig.3 shows the block diagram of a soft starter circuit. In the soft starter again the IGBT‟s are used as the switches. It consists of zero crossing sensing, control circuit and soft starter (anti-parallel IGBt‟s). The zero crossing is used to know where exactly the input voltage is crossing the zero point, depending upon the zero crossing of the input voltage the particular switch of the starter circuit is turned on. By controlling the gate pulses of the switches we are giving the controlled voltage at the motor input terminals.

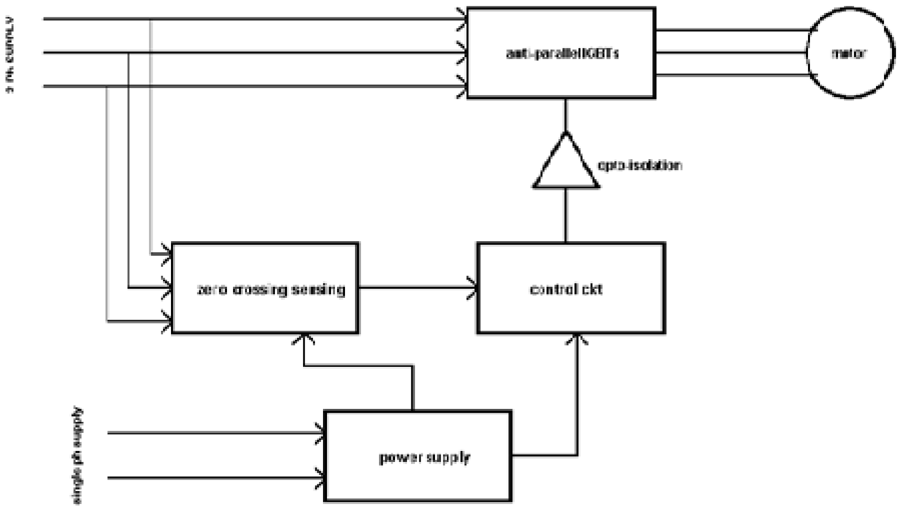


Fig 3: Block diagram of a soft starter

II. DEVELOPMENT OF CONSTANT VOLTS/HERTZ MOTOR DRIVE

A. Theory of Constant Volts/hertz Induction Motor Drive: The constant Volts Hertz control method is the most popular method of Scalar control, controls the magnitude of the variable like frequency, voltage or current. The magnitude of stator flux is proportional to the ratio of stator voltage and the frequency. If ratio is kept constant the stator flux remains constant and motor torque will only depends upon slip frequency. Open-loop speed control of an induction motor provides a satisfactory variable speed drive when the transient performance characteristics are undemanding and when the motor operates at steady speeds for long periods. The demerit of this system is that it cannot be used in the presence of supply voltage fluctuations and loads disturbances. Also, when the drive requirements include rapid acceleration and deceleration, an open-loop system is unsatisfactory because the supply frequency cannot be varied quickly without exceeding the rotor breakdown frequency. However, when fast dynamic response and greater speed accuracy are needed, closed-loop control methods are essential, but a precise feedback system must be used to sense the rotor speed and adjust the inverter frequency accordingly. For adjustable speed applications, variable voltage and variable frequency is prevalent. The simple principle is to keep stator flux($\Psi s=Vs/\omega e$) constant by changing voltage with proportional to frequency. Fig.4 shows the block diagram of the Volt Hz speed control method. The power circuit consists of a diode rectifier with three phase AC supply, capacitor filter, and PWM voltage-fed inverter. The frequency command ωe is the control signal, neglecting the small slip frequency ωsl of the machine. Based on Volts Hz control theory which has been mentioned in the above section, the phase voltage command Vs* can be generated from frequency command be the gain factor K, as shown, so that the flux Ψs remains constant. If the stator resistance and leakage inductance of the machine are neglected, the flux will also correspond to the air gap flux Ψm or rotor flux Ψr . At low speed areas, the stator resistance becomes significant and absorbs the major amount of the stator voltage, thus weakening the flux. Therefore, the boost voltage Vboost is added to compensate flux to keep it equal to rated flux and corresponding full torque become available at low frequency. The ωe signal is integrated to generate the angle signal θe and the corresponding sinusoidal phase voltages (Va* Vb* Vc*)are generated by the expressions shown in the Fig.4 Then PWM controllers which are embedded in digital signal controller can generate control signals to drive the inverter.

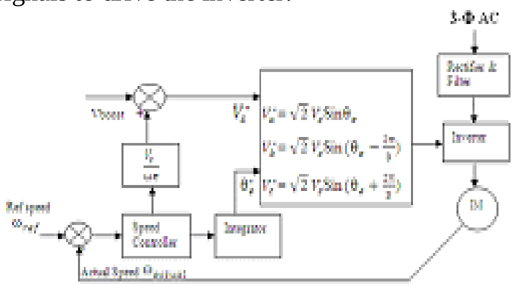


Fig 4: Closed loop Volts Hz speed control with voltage-fed inverter

B. General Structure of the System: The basic block diagram of a three phase induction motor drive with soft starter is shown in Fig.1 and Fig.2. It is consisting of the following blocks

1)Three phase full bridge rectifier.
2) Three phase full bridge inverter.
3) Control circuit.
4) Speed sensing unit.
5) DC regulated power supply.
6) Output filter.
7)Soft starter.

1. Rectifier and Inverter unit:In the present work a three phase uncontrolled (diode) bridge rectifier is used. To protect the power diodes from high dv/dt during switch „on" of the supply to the system, three Metal Oxide Varistors (MOV's) are used. A capacitor filter bank is used in the dc link (this also gives the centre-tapped point in the dc link). The full bridge inverter is designed by using six power IGBT's viz. I1, I2, I3, I4, I5 and I6 with anti-parallel diodes across each IGBT. To avoid simultaneous turn-on of the IGBT's of the same leg during firing sequence, a dead-gap is given between switch-on and switch-off of IGBT's of the same leg. The dead gap is made longer than the max turn-on time and turn-off time. Fig.5. shows the gate pulse for I1. The rapid application or reapplication of voltage to a device can cause the device (IGBT) to trigger spuriously, or to turn on partially. When such rapid and excess surges are anticipated, then voltage snubbers are to be employed. In the present design RC type of snubber is used.

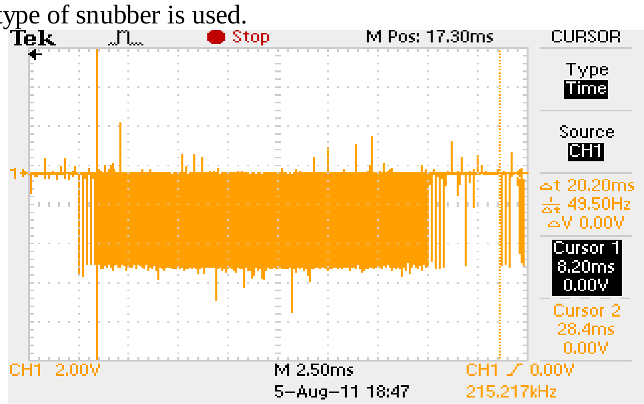


Fig 5: Gate pulse for firing the IGBT

2. Control Block: It mainly consists of a dsPIC30F2010controller, the brain, and six opto-coupler systems for isolating the controller and power circuits. The dsPIC controller is programmed so as to modify the frequency in order to attain the selected speed. The dsPIC is the combination of both DSP and micro controller.

The dsPIC has six PWM output channels which are sufficient to drive the six switches of the inverter so there is no need of additional analog circuits. The dead time is provided in order to avoid overlapping of turn „on" for upper and lower switch. In this work for motor control drive dsPIC30F2010 controller is used, which is of comparatively low cost as compared to the DSP processor. It is programmed to vary the frequency of the six gate pulses. Since the inverter is of square wave VSI, there is no need of additional hardware for generating the PWM waves for triggering the gates.

3. Power Supply*:* Since, six gates are to be fired independently in the three phase bridge inverter; provision is made for this in the present work. Power supply section is designed to provide independent supplies for different sections. Three for firing upper three gates and one for firing the lower three gates (lower gates have common ground) and in soft starter for each switch power supply is given independently. The one supply is used for digital signal controller, RPM sensor, LCD display and Zero crossing sensing.

4. Speed Sensing Unit:It is a simple LED-photo diode system, the light path between which is obstructed the number of times proportional to the rpm. The output is given to the digital signal controller for modifying of the gate pulses as per the requirement. There has to be trade-off between the response time of achieving the selected speed and the accuracy. Better accuracy and response time can be achieved by increasing the number of obstructions per revolution. For one obstruction per revolution the response time of increasing /decreasing speed will be 10 rpm/6sec and the accuracy will be ±10 rpm. To increase the response time six obstructions per revolution are used giving response time of increasing /decreasing 10 rpm/sec and the accuracy of ±10 rpm.

5. Filter Unit: The output voltage of the inverter is of square wave shape. It has harmonics of order pq±1. Since inverter is six pulse inverter, the harmonics which are predominantly present are of order 5, 7, 11, 13, 17… In the present work, a passive filter (LCR) is used at the inverter output to reduce the effect of the harmonics.

6. Soft Starter: The soft starter topology employed in the present work is adopted from [5] in which the author has compared the Performance Analysis of Thyristor and IGBT based induction motor soft starters. In the present work the IGBT based induction motor soft starter is developed and analyzed in terms of starting current, starting voltage and starting torque for different gate voltages.

III. RESULTS AND ANALYSIS OF THE DESIGNED SYSTEM

A. Experimental results and analysis of speed Control: Various readings for various speed-load combinations are taken. Table no.1, 2 and 3 shows the reading for various loads, for the RPM's 1440 and 1350 respectively. Fig. 7 and 8 show the various characteristics for the set RPM's of 1440 and 1350 respectively. Fig.6s shows the frequency variation of gate pulse for different speeds.

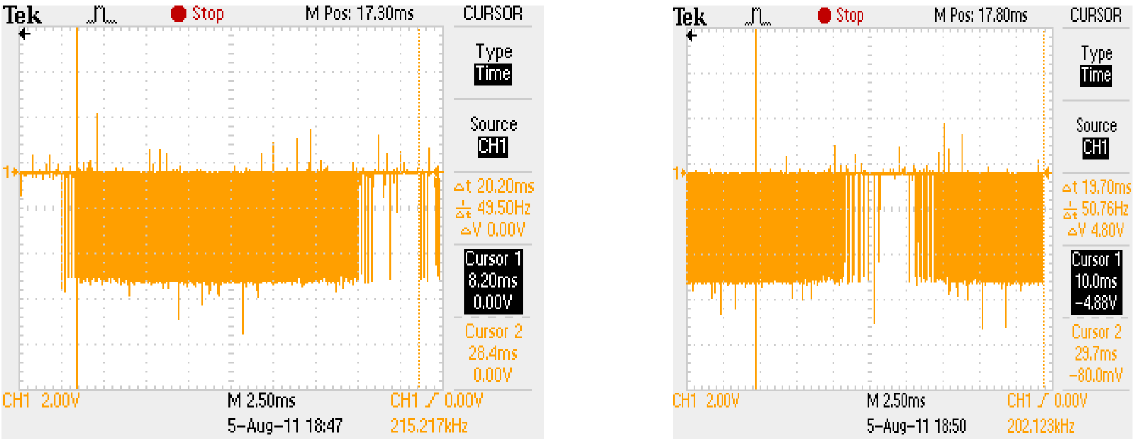


Fig.6: Gate pulses at 500gm load for 1440, 1350 RPM's

In the experiment 98% accuracy of speed control is recorded. It is deduced from the speed vs load graph that the speed is nearly constant by maintaining the ratio V/f constant.

Table-1:Results for load vs 1440 rpm

Sl.No	Load in gms	Actual RPM	Frequency of Vout	Current (A)
1	500	1320	45.84	0.6
2	1000	1410	47.24	0.63
3	1500	1410	48.23	0.63
4	2000	1410	45.20	0.63

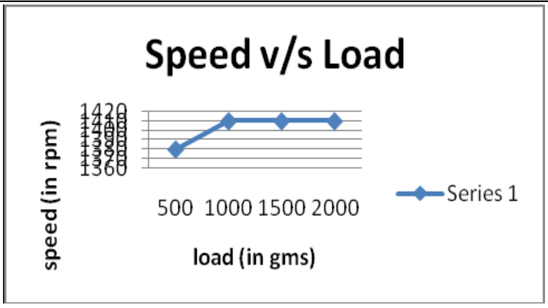
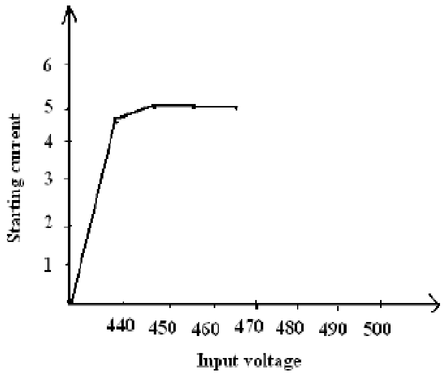


Fig 7: Characteristics of actual RPM vs load for the set speed of 1440

B. Experimental results and analysis of Starting current with and without soft starter:By designing the IGBT based induction motor soft starter the starting current is reduced to 30% to 50% of its rated current. The developed IBBT based soft starter is included in the motor drive system and the starting current and voltage are noted. The induction motor starting current and voltage are tabulated in Table.4 for with and without soft starter.

Table 2: Details of starting current with and without Soft starter.

Without soft starter		With soft starter	
Input voltage	Starting current	Input voltage	Starting current
380	3.8	380	0.91
390	3.5	390	0.92
400	3.2	400	0.95
405	3.8	405	0.95
410	4.9	410	0.97
415	5	415	0.98



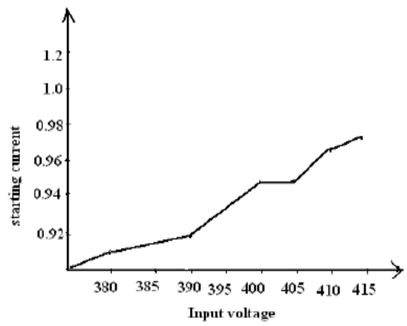


Fig 9: Starting current curve without soft start Fig10: Starting current curve using soft start

By observing Fig. 9 we can say that the starting current of motor without soft starter is 3 to 5% more than the rated current. In this work by including the soft starter the starting current and voltage are reduced to 30% to 50% of the full load current as shown in Fig. 10. In this paper by controlling the gate voltage we can give the controlled voltage at motor input so that the starting current can be reduced substantially. The gate pulse and line-line voltage for different gate voltages of 1V, 2V and 5V are observed using Textronix TDS2024B Digital storage Oscilloscope.

Fig 11. Photograph of the complete designed system

IV.CONCLUSION

The complete system is tested in power electronics laboratory. The experimental results obtained using the designed three phase motor drive system are studied in two parts, namely, the control part and the soft starter part. The control of motor speed is acquired with an accuracy of ±10 rpm. The selected rpm is locked irrespective of change in load. The different gate pulse and voltages are seen on oscilloscope. The soft starter circuit used suppressed the starting current significantly. With this we can conclude that by using the soft starter the starting losses will be reduced by 50%, so that heating of the motor can be avoided and at the same time it will result in the increased life of the motor.

REFERENCES

[1] Adel Gastli and Mohamed Magdy Ahmed, "ANN Based Soft Starting of Voltage Controlled IM Drive System". IEEE Trans on Energy Conversion, VOL-20,No-3, sSeptember 2005.

[2] Frank M. Bruce, Richard J. Graefe, Arthur Lutz and Michel D. Panlener, "Reduced Voltage Starting of Squirrel Cage Induction Motors". IEEE Trans on Induction Applications, VOL. 1A-20, No-1, January/February 1984.

[3] S.A. Hamed and Prof. B.J.Chalmers, "Analysis of Variable Voltage Thyristor Controlled Induction Motors". IEEE Proceedings, Vol.137, Pt.B.No.3, May 1990.

[4] G. Bhuvaneswari, Charles. S and Manjula G. Nair. "Power Quality Studies on a Soft Start for an Induction Motor". 978-4244-1904-3/08/$25.00 2008 IEEE.

[5] Ahmed Riyaz, Atif Iqbal, Shaikh Moinoddin, SK. MoinAhmed and Haitham Abu-Rub "Comparative Performance Analysis of Thyristor and IGBT based induction motor soft starters". International journal of engineering, Science and Technology Vol.1, No.1, 2009, pp. 90-105.A. M. Eltamaly, A.I. Alolah and R.M.Hamouda "Performance Evaluation of Three Phase Induction Motor under Different AC Voltage Control Strategies". 1-4244-0891-1/07/$20.00 2007 IEEE.

[6] Werner Deleroi, Johan B. Woudstra and Azza A.Fahim "Analysis and Application of Three Phase Induction Motor Voltage Controller with Improved Transient Performance". IEEE Trans. on Industry applications, Vol-25. No-2, March/April 1989.

[7] M. G. Solveson, B. Mirafzal, and N. A. O. Demerdash, "Soft-Started Induction Motor Modeling & Heating Issues for Different Starting Profiles Using a Flux Linkage *ABC F*rame of Reference", IEEE Trans. Industry Applications, Vol. 42, No. 4, pp. 973-982, July/ August 2006.

[8] G. Zenginobuz, I. Çadırcı, *M*. Ermiş, and C. Barlak, "Performance Optimization of Induction Motors During Voltage-Controlled Soft Starting," IEEE Trans. Energy Conversion, *V*ol. 19, No. 2,pp. 278- 288, June 2004.

[9] V. V. Sastry, M.R. Prasad and T.V. Sivakumar, " Optimal Soft Starting of Voltage- Controller Fed IM Drive Based on Voltage Across Thyristor," IEEE Trans. Power Electronics, Vol. 12, No. 6, pp. 1041-1051, November 1997.

[10] G. Zenginobuz, I. Çadırcı, M. Ermiş, and C. Barlak, "Soft Starting of Large Induction Motors at Constant Current with Minimized Starting Torque Pulsations," IEEE Trans. Industry Applications, Vol. 37, No. 5,pp. 1334-1347, September/ October 2001.