Current Source Inverter fed Induction Motor Drives: A Survey

A. K. Srivastava*, S. M. Tripathi**

*M.Tech. Student
Department of Electrical Engineering
Kamla Nehru Institute of Technology Sultanpur-228118(U.P.), India
e-mail: aankit.srivastava32@gmail.com

**Assistant Professor
Department of Electrical Engineering
Kamla Nehru Institute of Technology Sultanpur-228118(U.P.), India
e-mail: mani_excel@yahoo.co.in

Abstract

This paper presents a comprehensive survey of the current source inverter (CSI)-fed induction motor (IM) drives. It also reviews various control methodologies, selective harmonic elimination techniques and methods for reduction in switching losses in CSI fed IM drives. Authors strongly believe that this survey article shall be very much helpful to the researchers working in the field of CSI fed IM drives for finding out the relevant references.

Keywords: Current source inverter, Direct torque control, Field-oriented control, Selective harmonics elimination, Switching losses.

1. Introduction

Power electronics has changed rapidly during the last thirty years and the number of applications has been increasing, mainly due to the developments of the semiconductor devices and the microprocessor technology. An overview of different power devices and the areas where the development is still going on is presented in Fig. 1 [1].

The voltage source inverter (VSI) fed drives are most widely used in low and medium power applications, but not used widely in high power applications. Now a days, current source inverter (CSI) fed motor drives are increasingly used for medium-voltage high-power applications where fast dynamic response is not needed because of the following advantages [2-4]:

- Simple converter topology,
- Inherent four quadrant operation,
- Reliability,
- Motor friendly waveforms with low $dv/dt$.

Fig. 1 Development of power semiconductor devices since 1950 [1]
Fig. 2 shows the functional block diagram of the conventional CSI drive. The present day CSI drives employ self commutating devices such as gate turn-off thyristors (GTOs) instead of SCRs as in the past. Pulse width modulation (PWM) techniques [5-25] can be used to get improved output currents and voltages. Even though a relatively high switching frequency PWM will result in near sinusoidal output voltages and currents, at higher power levels the CSI is switched at low frequency (200 Hz), to reduce switching losses.

![Functional block diagram of the conventional CSI drive](image)

Fig. 2 Functional block diagram of the conventional CSI drive

2. An Outline to Current Source Inverter fed Induction Motor Drives

Literatures on CSI-fed induction motor drives employing different control methodologies, selective harmonic elimination techniques and methods to reduce switching losses are outlined in this section.

Hatua et al. [26] presented a new configuration for high power induction motor drive in which induction machine is provided with two three-phase stator windings, one is excitation winding powered by an IGBT based voltage source inverter (VSI) with an output filter and second is power winding fed by a load commutated current source inverter (LCI). The commutation of the thyristors in the LCI is achieved by injecting the required leading reactive power from the excitation inverter. The m.m.f. harmonics due to the LCI current are also cancelled out by injecting suitable compensating component from the excitation inverter, so that the electromagnetic torque of the machine is smooth. Filsecker et al. [27] presented a complete design procedure for a current source converter (CSC) that consists of a PWM current source rectifier (CSR) and inverter (CSI) feeding an induction motor. The converter design is made so that the switches in the inverter operate at their maximum specified junction temperature. Raj et al. [28] proposed a new control strategy for induction motor drives fed by current source inverter in which a multivariable state feedback as well as feed forward control is applied for fast regulation and stability of the drive system. The design of the state feedback controller was based on the application of the pole assignment technique of industrial regulation theory to a d-q axes state space linearised model of the drive and includes a reduced order observer to obtain faster dynamic response. Basu et al. [29] proposed hybrid PWM technique to reduce the torque ripple considerably over conventional space vector PWM (CSVPWM) along with a marginal reduction in current ripple. Shahalami et al. [30] presented, a novel control approach of a CSI drive system using an induction motor in which a variant of hysteresis-band current control adapted to the current source inverter circuit topology is proposed. The current control strategy is based on the correction of the two out of three larger errors of the instantaneous real currents of motor with respect to their references. In order to suppress the inherent instability of current fed induction motor, a coefficient of derivative of real motor’s currents is added to the reference ones. Morawiec et al. [31] presented a control system for the induction motor fed by current source converter based on a multiscalar model, a new approach to the control of induction motor based on DC-link current and rotor flux vector in which speed observer system is applied to receive sensorless drive. Li
et al. [32] proposed a loss reduction and DC-link current minimization strategy for a high-power current-source inverter (CSI) fed drive. The proposed strategy consists of an inverter maximum modulation index control scheme and a flux optimization algorithm. With the proposed DC current minimization strategy, the losses in the semiconductor devices and the DC-link can be reduced, and the drive current rating could be lowered. Bierk et al. [33] showed that in high power applications the inverter of a motor drive should have a switching frequency as low as possible in order to reduce the switching and snubber losses. An effective pulse width modulation (PWM) approach that can be utilized successfully with high control accuracy is combination of selective harmonic elimination and pulse width modulation (SHEPWM). SHEPWM can optimize PWM output waveforms for selected harmonic elimination or to minimize total harmonic distortion (THD). This technique is used with voltage source inverters (VSI) and current source inverters (CSI) as well. Banerjee et al. [34] proposed a CSI-fed induction motor drive scheme where GTOs are replaced by thyristors in the CSI without any external circuit to assist the turning off of the thyristors. The current-controlled VSI, connected in shunt, is designed to supply the volt ampere reactive requirement of the induction motor and the CSI is made to operate in leading power factor mode such that the thyristors in the CSI are auto sequentially turned off. The resulting drive will be able to feed medium-voltage, high-power induction motors directly. Li et al. [35] presented a novel flux adjustment power-factor (PF) control strategy for a high-power pulse width-modulated current-source inverter-fed motor drive system. Unlike all the other PF compensation techniques, the proposed flux adjustment approach does not require online modulation index control of the rectifier and the inverter, and therefore, offline selective harmonic elimination modulation can be implemented on both the rectifier and the inverter to minimize the line-side and motor side waveform distortions. The proposed PF regulation method, together with a properly designed input line capacitor, can ensure a unity PF throughout the whole speed range (including flux-weakening range). Beig et al. [36] presented a novel CSI drive in which two identical multilevel inverters are used as active filters, one at the input end and another at the motor terminals with common DC bus. The active filter at input end provides necessary active current to maintain DC bus. Such an arrangement will ensure sinusoidal input currents, sinusoidal motor currents and motor voltages. The proposed configuration promises a better alternative compared to other conventional methods like use of passive filters or multi pulse rectifiers at the input stages in terms of cost and performance. Payam et al. [37] designed a nonlinear controller for doubly-fed induction machine (DFIM) drives based on adaptive input-output feedback linearization control technique using the fifth order model of induction machine in fixed stator $d-q$ axes reference frames with stator currents and rotor flux components as state variables. The nonlinear controller can perfectly track the torque and flux reference signals in spite of stator and rotor resistance variations. Two level SVM-PWM back-to-back voltage source inverters are employed in the rotor circuit in order to make the drive system capable of operating in the motoring and generating modes below and above synchronous speed. Mukherjee et al. [38] presented feed-forward control strategy for the LC filter to have a good bandwidth for the filter output voltage. This filter control strategy is introduced along with a sensorless vector control strategy for the SQIM drive. This complete strategy retains the high dynamic performance of the drive even with the LC filter. Qiu et al. [39] described the minimization of the line and motor-side harmonics in a high power
current source drive system. The proposed control achieves speed regulation over the entire speed range with enhanced transient performance and minimal harmonic distortion of the line and motor currents while limiting the switching frequency of current source converters to a maximum of 540 Hz. To minimize the motor current harmonic distortion, space vector modulation (SVM) and selective harmonic elimination (SHE) schemes are optimally implemented according to different drive operating conditions. Beig et al. [40] proposed a novel CSI drive which overcomes the drawbacks of conventional CSI drives such as harmonic resonance, unstable operation at low speed ranges, and torque pulsation and results in sinusoidal motor voltage and current even with CSI switching at fundamental frequency. A sensorless vector controlled CSI drive based on proposed configuration is developed. Rees et al. [41] presented a new DC-link current set value assignment and a method to improve the models for magnetizing current and field angle by using steady-state stator voltages. Imecs et al. [42] presented a tandem converter arrangement of two inverters connected in parallel: a high-power pulse-amplitude modulated current-source inverter and a low-power pulse-width modulated voltage-source inverter. Kwak et al. [43] presented a hybrid converter system employing a combination of a load-commutated inverter (LCI), a DC-DC buck converter, and a voltage-source inverter (VSI) for the large induction motor drives. The buck converter enables both the VSI and the LCI to be fed from the single-diode rectifier. As a result, the DC-link inductor size can be reduced and the LCI is operated without the controlled rectifier. In addition, faster dynamic response can be obtained through the VSI and the buck converter operation. Bojoi et al. [44] introduced a new multi-source fed drive topology based on a multi-phase induction machine. The reference application is the hybrid fuel cell (FC) traction system (fuel cell and battery). The FC power and the battery power are directly added at the machine level, without any additional DC-DC converters. The proposed drive topology uses two three-phase inverters having different DC link voltages provided by the FC and the battery, respectively. In this drive topology, the machine can operate asymmetrically and the control system must be able to cope with different power levels in the two sections of the drive. A rotor field oriented control strategy has been implemented using a stationary frame current control scheme. Nikolic et al. [45] presented a speed sensorless direct torque control (DTC) implementation in a current source inverter (CSI) fed induction motor drive. DTC of a CSI fed induction motor drive involves the direct control of the rotor flux linkage and the electromagnetic torque by applying the optimum current switching vectors. For sensorless control of the drive, an improved estimator is applied using stator voltages and currents. The stator current, voltage and resistance are not measured, but determined by a reconstruction from DC link measurements and the inverter switches states. Mohapatra et al. [46] presented a harmonic elimination and suppression scheme for a dual-inverter-fed open-end winding induction motor drive. Two isolated DC-link sources with voltage ratio of approximately 1:0.366 are required for the presented drive. These two isolated DC-links feeding two inverters to drive the open end winding induction motor eliminate the triplen harmonic currents from the motor phase. Kwak et al. [47] presented a novel, hybrid solution employing a combination of a load-commutated inverter and a voltage-source inverter for the induction motor drives. By avoiding the use of output capacitors and a forced DC-commutation circuit, this solution can eliminate all disadvantages related with these circuits in the conventional load commutated inverter based induction motor drives. In addition, improved quality of output current.
waveforms and faster dynamic response can be achieved. Kwak et al. [48] presented a current-source based rectifier / inverter topologies used in medium and high power AC drive applications. Reference [48] also presents the theoretical analysis and mathematical derivations for the two topologies - one with a PWM current source rectifier (PWM-CSR) and the other using a thyristor rectifier in parallel with an active filter in order to achieve unity power factor in the utility lines. The two drive systems are systematically compared. Bojoi et al. [49] presented a direct rotor-field-oriented control of a dual-three phase induction motor drive. The stator windings are fed by a current-controlled pulse width-modulation (PWM) six-phase voltage-source inverter. Three key issues are discussed: (a) the machine dynamic model is based on the vector space decomposition theory; (b) the PWM strategy uses the double zero-sequence injection modulation technique which gives good results with low computational and hardware requirements; and (c) to eliminate the inherent asymmetries of the drive power section, a new current control scheme is proposed. Salo et al. [50] presented vector controlled current-source PWM inverter fed induction motor drive. The vector control system of the induction motor is realized in a rotor flux oriented reference frame, where only the measured angular rotor speed and the DC-link current are needed for motor control. Methods to damp the stator current oscillations and to compensate the capacitive currents drawn by the load filter are presented. The proposed methods operate in an open-loop manner and can be realized without measurement of any electrical variable. Salo et al. [51] presented a high performance vector controlled PWM current source inverter (PWM-CSI) fed induction motor drive where only the measured rotor angular speed and the DC-link current are needed for motor control. Novel methods for compensating the capacitive currents of the motor filter and damping the motor current oscillations in the transient conditions are presented. Espinoza et al. [52] analyzes the existing motor drives based on current-source topologies and proposes a control strategy that addresses some of the drawbacks of this approach compared to the voltage-source approach. The proposed strategy features the following: (a) an on-line operated PWM inverter using instantaneous output capacitor voltage control based on space-vector modulation and (b) an additional inverter modulation index control loop ensuring constant inverter modulation index and minimum DC-link current operation. The resulting additional advantages include the following: (i) fixed and reduced motor voltage distortion; (ii) minimized DC-bus inductor losses; (iii) minimized switch conduction losses; and (iv) elimination of motor circuit resonances. Mohamed et al. [53] utilized the $H_\infty$ loop shaping design procedure (LSDP) with $\mu$-analysis (\(\mu\) LSDP) to design a controller for a CSI-fed induction motor drive system in order to achieve robust stability and robust performance against various model uncertainties. Lee et al. [54] presented a novel control strategy for induction motor drives fed by PWM current source converter and inverter system. A multivariable state feedback control with feed-forward control is applied for the improved control of both the converter input and inverter output currents, which gives fast transient responses. Dakir et al. [55] presented a control system for PWM current source inverter (CSI) fed induction motor which has an estimator whose principal function is to perform contemporary calculations of rotor flux magnitude and induction machine load angle. Machine rotor flux observation-error was checked at static and dynamic states of the entire drive system, taking into consideration: the changes in stator and rotor resistances the stator current frequency and various estimator sampling
periods. Jamshidi et al. [56] suggested a simpler speed controller to eliminate the steady state error due to load changes in speed response of closed-loop control of currents source inverter fed induction motor drive. This simple controller makes use of normal PI controller with the concept of reduction of disturbance by prediction. The change of load torque of the motor itself is considered as disturbance and the linear relation between slip and torque has been utilized in the design of the controller to improve the performance. Jamshidi et al. [57] presented a self organizing fuzzy controller applied in closed loop speed control system of an induction motor fed from auto sequential current source inverter. The induction motor is controlled to operate in constant flux mode. Ide et al. [58] presented a simple adaptive control (SAC) with exact linearization for the current source inverter (CSI) fed induction motor drive. SAC has the robust characteristics concerning disturbance and the effects of un-modeled dynamics. The proposed system can improve the fast tracking of set command change without overshoot and the recovering time of speed at the sudden-load variations. Mok et al. [59] presented a load-commutated current source inverter (LCCSI) induction motor drive system employing a novel DC-side forced commutation circuit for machine start-up. To avoid the adverse effects of harmonic resonance between the output capacitor and the inductance of the induction motor, a solution is proposed using a special type of one-notch current PWM, fully utilizing the proposed commutation circuit. A direct vector controller, which refers to the fixed reference frame of the rotor flux without using a speed sensor, is applied. In addition to compensating for the capacitive current, this controller is applied to decouple the torque and flux generating currents and to overcome the instability caused by the output capacitor. Kleinhans et al. [60] developed a model of the current source inverter (CSI)-fed induction motor drive using a new variable speed drive simulation package CASED. This model includes rectifier, inverter and induction motor dynamics. The drive speed control is based upon indirect field oriented control (FOC).

3. Control Methodologies used in CSI fed IM Drives

DTC is the latest AC motor control method [61] developed with the goal of combining the implementation of the $V/f$ based induction motor drives with the performance of those based on vector control. The literature related to AC drives covering scalar control, field-oriented control, and direct-torque control (DTC) has been well documented in [62]. So far, the vector control (VC) and direct torque control (DTC) methods have been applied to the squirrel cage induction machine drives [63].

Field oriented control is one of the most used control methods of modern AC drives systems. The basic idea behind this control method is to transform the three phase quantities in the AC machine in an orthogonal $d_q$ system aligned to one of the fluxes in the machine. Thus, a decoupling in controlling the flux and electromagnetic torque of the machine is achieved. Two methods of field oriented control for induction machines are used namely: indirect and direct vector control. Each of these methods has advantages and drawbacks. The indirect vector control can operate in four-quadrants and it is widely used in both motor drives and generator applications. Typically the orthogonal synchronous reference frame is aligned on the rotor flux. However, this control is highly dependent on machine parameters. The direct vector control oriented along the stator flux does not need information about the rotor speed and is less sensitive to the machine parameters. However, it presents low performances for low speeds near to standstill. A general control
The electromagnetic torque is controlled in $q$-axis while the $d$-axis controls the flux of the machine. The actual flux and torque as well as the flux angle are determined based on the machine equations using the currents. In rotor field-oriented control of CSI fed induction machines, the current control is the inner loop of the system. It receives the flux-producing and the torque-producing reference values from the outer loops (flux loop and torque / speed loop) in $(d, q)$ rotor flux synchronous reference frame. The current control can be implemented either in synchronous $(d, q)$ [64-65] or in $(\alpha, \beta)$ stationary reference frame. The synchronous $(d, q)$ current control scheme developed in [64-66] relies on the DTP modeling approach and employs a set of four PI $(d, q)$ current controllers (two for $d$ and two for $q$ axes current components). Each of the two $(d, q)$ current controller pairs produces stator voltage references for one of the two three-phase windings. This solution has the advantage of zero-steady state error obtained with PI regulators, but there are multiple speed dependent $(d, q)$ coupling terms; at high speed these coupling terms must be compensated with quite complicated decoupling networks to obtain satisfactory performance and stability [64]. Field-oriented control (FOC) schemes are widely employed to achieve improved system dynamics and reliability by controlling the flux and torque independently. To further improve the system performance and / or reduce the costs, research efforts have been recently put on new current source drive topologies [2-4], [67]; advanced modulation scheme development [68-73]; control performance improvement [74-77], etc.

Direct torque control of induction motor was proposed around two decades ago. The direct torque control (DTC) is one of the actively researched control schemes of induction machines that provide a very quick and precise torque response without the complex field-orientation block and the inner current regulation loop [78-79]. The scheme presented in [78] was implemented for high power applications using an induction motor having open-end winding configuration [80].

However, the DTC technique presented in [80] results in:

- Torque and speed fluctuations which lead to acoustic noise and vibrations.
- Higher ripple in the stator current that can cause power loss and hence heating of the machine.
- Use of a three-phase reactor to reduce the zero sequence current, make the system bulky.

![Fig. 4 General structure of the direct torque control for AC machines.](image)
The direct torque control proposed by Depenbrock eliminates the inner current loops and the needs of transformations between different references frames. It controls directly the magnitude of the stator flux and the electromagnetic torque of the machine by using hysteresis comparators as shown in Figure 4. The outputs of the hysteresis comparators as well as the flux angle are used directly to determine the switching states of the converter. The control strategies of conventional DTC scheme are given in [78-79], [89]. There are also another DTC-based strategies, presented in [79], [81-82]. High performance induction motor drives employing DTC strategies with various variables have been reported [78-79], [83].

4. Selective Harmonics Elimination Techniques used in CSI fed IM Drives

An interesting and suitable topology called the open-end winding induction motor drive is presently being studied for high-power applications [84-87]. The inverters are fed from DC-link sources of half the magnitude, when compared to the same in conventional two-level inverters [84]. In order to avoid the flow of triplen harmonic currents in the motor phase, isolated DC-link power sources or harmonic filters are required for these drives [84-86]. These fundamental and harmonics resonance problems have seriously restricted the system performance. Inherent instability in the high-frequency region can be caused by the output capacitor [88]. Active filters are successfully used in utility applications to filter out the harmonics from the supply currents. Active filters result in better performance compared to passive filters [89-90]. An LC filter is normally required at the input of a PWM CSR to mitigate the converter switching harmonics. To avoid the steady state LC resonance during the drive operation, the input LC filter for a PWM CSR need to be designed carefully [91]. A powerful vector space decomposition approach has been introduced in [92] to obtain the machine model and to obtain a PWM technique which considerably reduces the current harmonics with some implementation problems caused by the required computational time. To reduce the computational requirements, other PWM techniques have been presented in [93-94]. The non sinusoidal motor current drawn from the LCI can produce considerable losses and harmonics, holding the LCI drives back from high performance [95-96]. Moreover, the square wave motor current waveforms in low speed region, rich in low order harmonics, can produce voltage spikes in stator leakage inductance of the motor, potentially hazardous for the winding insulation [95].

Selective harmonic elimination PWM is an optimizing algorithm that gives a superior harmonic performance in high power applications with the minimum switching frequency [97-98].

The conventional PWM-CSI applications are reported in many literatures [99-101]. So far, almost all progress in the performance of CSI-AC machine drives are limited to the new PWM techniques such as trapezoidal PWM, selected harmonic elimination PWM and so on [101]. Due to the advent of a self-commutated device GTO, a PWM CSI was developed by Hombu [101]. PWM switching strategy itself and control techniques for PWM CSI fed induction motor drives have been proposed to improve the output current harmonics [102-103]. Since then, a few methods to apply the instantaneous PWM have been issued [104-105]. This has resulted in the widespread use of selective harmonic elimination (SHE) stored patterns [102-103], [106] usually with a fixed modulation index.

On-line control of the CSI requires complex control [102] and / or power circuitry [107] which has led to two main control approaches:
• Control schemes that use stored patterns (such as SHE) and variable DC-link current to control the output current

• Control schemes that use fixed DC-link current and a variable modulation index of the PWM generator at the CSI stage to control the output current.

Fig. 5 Typical waveform for SHE-PWM technique

To eliminate 5th and 7th harmonics a set of three nonlinear equations is required to be solved in order to compute the three switching angles \( \alpha_1, \alpha_2, \) and \( \alpha_3 \) as shown in Fig. 5 which illustrates the three levels SHEPWM that we use to eliminate 5th and 7th harmonics. It is well known that the switching angles cannot be computed directly. This heavy computational process is considered as the main drawback of SHE technique [108]. Numerical processes may be employed to solve these equations at different modulation indexes [109]. The presence of capacitor at motor terminals gives rise to two modes of resonance namely fundamental frequency resonance and harmonic frequency resonance [110-111]. The fundamental frequency resonance is avoided by selecting the capacitor (C) such that fundamental frequency resonance lies well above the operating speed of the drive. Hence the value of capacitor decides upper limit on the motor speed. In order to avoid the harmonic frequency resonance, the selected harmonic PWM (SHPWM) is generally employed [110-111]. Reference [111] describes a conventional CSI drive, which employs selective harmonic elimination PWM technique that results in acceptable waveform quality at low switching frequency. Harmonic distortion improvement of a current source drive system is either focused on the motor side [110] or on the line side [112]. In Reference [110] a combination of off-line selective harmonic elimination (SHE) technique and the trapezoidal pulse width modulation (TPWM) was proposed for the CSI, where the TPWM was applied for stator frequency lower than 20 Hz while the SHE was used when the stator frequency is higher than 20 Hz. However, at very low stator frequencies, low order harmonics produced by the TPWM scheme may have a high magnitude. For the line-side harmonic performance improvement, an active damping method based on virtual harmonic resistor concept was proposed to reduce the line current resonant harmonics caused by the line-side LC filter [112]. Considering the low switching frequency (normally around 500 Hz) for high-power converter applications, without SHE modulation, the line current distortion will be serious due to the significant low-order harmonics (such as the 5th, 7th, and 11th), especially when the input LC resonance caused by the filter is not properly damped [113-114].

5. Methods to Reduce Switching Losses in CSI fed IM Drives

In order to reduce inverter switching losses and limit the ripple currents in the motor phase multilevel inverters of the type three-level, five-level, etc., [115-117] are preferred to the conventional two-level inverter for high-power drive applications. System efficiency is one of the most important factors to improve energy savings and reduce the costs. Many studies in the literature have been carried out to improve the efficiency of a drive and motor system [118-125]. However, most of them focused on medium or low-power applications with an emphasis on the motor efficiency, while the drive system losses are either omitted [118-123] or not
adequately considered [124-125]. Because of hard-switching in conventional PWM inverters, the switching losses in the devices are high and the windings of induction motor are subjected to high switching stresses. To overcome these problems, soft-switching strategies [126] have been actively considered for the inverter-fed induction motor drives. The LCI-based drive employs converter grade thyristors and utilizes soft switching by natural commutation of the thyristors. Therefore, it provides simplicity, robustness, cost effectiveness, and very low switching losses, resulting in a favorable topology in high-power areas [127]. Moreover, because it has the current-source inverter (CSI) topology, it has inherent advantages of CSI, such as embedded short-circuit protection, improved converter reliability, and instantaneous regeneration ability [128]. Due to all of these features, much research has been conducted in the last two decades to control the LCI-based induction motor drive and improve its performance, especially in medium-to-high-power applications [88], [127], [129-132].

6. Conclusions

The paper has attempted to give a survey of the recent developments and trends in the field of current source inverter (CSI) fed induction motor (IM) drives. The paper has focused on the continuing researches on the different control methodologies of the CSI drives. It is concluded that the direct torque control methodology provides a better dynamic torque response whereas the vector (field-oriented) control methodology provides better steady-state behavior of the drive systems. Various techniques for selective harmonic elimination and methods to reduce switching losses in CSI fed IM drives have also been explored through this survey. Selective harmonic elimination PWM is an optimizing algorithm, which with the minimum switching frequency, gives a superior harmonic performance in high power applications. To overcome the problems of hard-switching in conventional PWM inverters, soft-switching strategies have been actively considered for the inverter-fed induction motor drives. Much research has been conducted in the last two decades to control and improve the performance of the LCI-based induction motor drives that employ converter grade thyristors and utilize soft switching by natural commutation of the thyristors and hence, minimize the switching losses.

Authors strongly believe that this survey article will be handy to the researchers in searching out the relevant references as well as the previous work done in the field of CSI drives, encouraging them for their future works.

References


A. K. Srivastava and S. M. Tripathi


Current Source Inverter fed Induction Drive Systems

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Current Source Inverter fed Induction…


Biographies

Ankit Kumar Srivastava received his B.Tech Degree in Electrical Engineering in 2008 from the VBS Purvanchal University, Jaunpur (U.P.), India. Currently, he is pursuing M.Tech in Power Electronics and Drives in Department of Electrical Engineering, Kamla Nehru Institute of Technology, Sultanpur, (U.P.), India. He obtained his B.Tech. degree in Electrical Machines, Control Systems, Power Electronics and Electric Drives.

Saurabh Mani Tripathi is presently working as Assistant Professor of Electrical Engineering at Kamla Nehru Institute of Technology, Sultanpur, (U.P.), India. He has authored several books on ‘Modern Control System’ and ‘Basic System Analysis’. His areas of current interest include Electrical Machines, Control Systems, Power Electronics and Electric Drives.