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Design and Implementation of Speed Regulation of Z-Source Fed Induction Motor

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Abstract— Induction motors which are used as electrical drives show good potential and used widely in electromechanical systems in various industry due to its own characteristics viz. durability, ruggedness, reliability, mechanical structure, low maintenance and comparatively low cost. Induction motors are now preferably used in a new generation of electrical transporting systems such as cars, buses, and trains. The present work emphasize on a novel technique to deal with voltage and current source fed induction motor problems regarding speed regulation using Z-source inverter. DC input voltage can be boosted up by Z -source inverter with no requisite of step up transformer or DC-DC boost converter , hence it prevails over the margins of output voltage of conventional VSI as well as decrease its rate. A comparison among conventional DC-DC boosted, Z-source inverter and PWM inverter illustrates that Z source inverter requires least semiconductors and control the cost of circuit, which are the main cost of a power electronics system which result in increase of concentration on z-source inverter.

The outcome arrived from the present work shows that the proposed algorithm can provide good speed regulation at specified reference speed with very high accuracy. The results also indicate that amount of feedback torque highly influence speed regulation process, hence a statistical analysis is also presented to provide complete speed regulation characteristics dependency on feed back torque.

Index Terms—Z source Inverter, induction motor, speed regulation, feedback torque.

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1 Introduction

RESEARCHER in the present time aimed their works in the development of the efficient control algorithms for high performance induction motor (IM) drives which operates at variable speed. Induction motor has been operated as a work horse in the industry due to its satisfactory efficiency, high strength as well as easy to manufacture. Recent development of high speed power semi conductor devices, three phase inverters take part in the key role for variable speed induction motor drives. Conventionally, Three Phase inverters with six switches (SSTP) have been commonly utilized for variable speed IM drives; this involves the losses of the six switches and the difficulty of the control algorithms and interface circuits to generate six PWM logic signals. So far researchers mainly concentrated on the development of new control algorithms. However, the cost, simplicity and flexibility of the overall drive system which are some of the most important factors did not get that much attention from the researchers. That is due to the fact that, in spite of remarkable research in this field, industries are not taken interest in this developed control system. Recently, some rigorous efforts have been made on the application of Four Switch Three Phase (FSTP) inverter for variable speed drives. Some advantages of the FSTP inverter over the conventional SSTP inverter such as, reduced price due to reduction in number of switches, reduced switching losses, reduced number of interface circuits to supply logic signals for the switches, simpler control algorithms to generate logic signals, less chances of destroying the switches due to lesser contact among switches and less real time computational burden.

The conventional inverters are Voltage Source Inverter (VSI) and Current Source Inverter (CSI), which consist of diode rectifier front end, DC link and Inverter Bridge. In order to improve power factor, AC inductor/ DC inductor is normally used. The DC link voltage is roughly equal to 1.35 times the line voltage and the Voltage source inverter is a buck converter that can only produce an AC voltage limited by the dc link voltage. Because of this nature, the Voltage source inverter based PWM VSI and CSI are characterized by relatively low efficiency due to switching losses and considerable Electromagnetic Interference (EMI) generation.

The fly back converter or boost converter with energy storage or diode rectifier provides another option to achieve ride-through. However, using these some new inadequacy viz. penalties of cost, size, weight and complexity come across. Inrush and harmonic current from the diode rectifier can infect the line. Conventional drives have another issue of low power factor. Performance and reliability are compromised by the voltage source inverter structure, because misgating from EMI can cause shoot- through that leads to destruction of the inverter, the dead time that is needed to avoid shoot through creates distortion and unstable operation at low speeds, and common mode voltage (CMV) causes shaft current and premature failures.of the motor. In a traditional voltage source inverter, the two switches of the same phase leg can never be gated on, at the same time, because, such activity would cause a short circuit (shoot-through) and would destroy the inverter. In addition, the maximum output voltage obtainable can never exceed the dc bus voltage. These restrictions can be conquer by the proposed Z- sourced inverter that uses an impedance network (Z-network) to replace the traditional DC link. The Z-

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source inverter advantageously utilizes the shoot-through states to boost the DC bus voltage by gating on both the upper and lower switches of a phase leg. Therefore, the Z-source inverter can buck and boost voltage to a desired output voltage that is greater than the available DC bus voltage. In addition, the reliability of the inverter is greatly improved, because the shoot-through can no longer destroy the circuit. Thus, it provides a low cost, reliable and highly efficient single stage structure for buck and boost power conversion. This maximum constant boost control can greatly reduce the L and C requirements of the Z-network.

The conventional three phase Pulse Width Modulation (PWM) inverter and a three phase PWM inverter with a DC-DC boost converter are two existing inverter topologies which are currently used for induction motor drives and very popular also in other applications like hybrid electric and fuel cell vehicles. Because of the wide voltage range and limited voltage level of fuel cell stack, the conventional PWM inverter topology imposes high stresses to the switching devices and motor. The DC-DC boosted PWM inverter topology can alleviate the stresses and limitations, but suffers from problems such as high cost and complexity associated with the two stage power conversion.

The newly proposed reduced switch Z-source inverter has the unique factor that it can boost the output voltage by introducing shoot through operation mode, which is forbidden in conventional voltage source inverters. With this unique feature, the Z-source inverter provides a cheaper, simpler, single stage approach. Moreover, it highly enhances the reliability of the inverter because the shoots through can no longer destroy the inverter. The present work includes analysis and comparisons of these inverters for induction motor drives using total Switching Device Power (SDP), passive components requirement and cost as bench marks. As it is well known that the high frequency common mode voltage produced by the pulse width modulated inverter source causes many problems in application of ac machine drives. It mainly causes a leakage current in motor winding, high shaft voltage, radiation of electromagnetic interference noise as well as other harmful by-products. During the last decades, many studies have been investigated to reduce the Common mode voltage (CMV) in conventional boost rectifier/inverter. Some of them concentrate in designing several common-mode sinusoidal output filters to reduce both differential and common mode dv/dt at the motor terminal. The others suggested variety of PWM schemes for reducing CMV in diode rectifier/inverter as well as rectifier/inverter system. These works have been focused on eliminating zero voltage vector (ZVV) of the PWM scheme by means of using two additional active vectors instead of ZVV in that of the conventional scheme, or shifting active voltage vector of inverter to align to those of the boost rectifier for disappearing one CMV pulse in every control period. Even though CMV can be mitigated by the above methods, they also require a high extra hardware, complexity in its control, or deteriorating reliability and lifetime of system. Recently, the Z-source inverter was proposed and applied to AC machine drive applications.

2 Z-Source Inverter

To overcome from the problems of the conventional V-source inverter and I-source inverter, new impedance – source (Z-source) power inverter has been recently invented and using in ac/dc power conversion applications. The schematic of the general Z-source converter structure is shown in Fig. 1. Both types of power sources i.e. voltage source or current source are used as input in Z-source power inverter. Z-source inverter consists of a unique impedance network which couple the converter main circuit to the power source/ load/ other converter [3], for providing unique features that cannot be observed in the usual voltage as well as current source inverters. The impedance network consists of two inductors and two capacitors connected to each other as shown in the Fig. 1, which is similar to the second order filter network. The values of both inductor and both capacitor are equal. The two inductors can be two separate inductors or two inductors inductively coupled to each other on a single core. For size and cost reduction film capacitors of desired value and voltage rating can be selected.

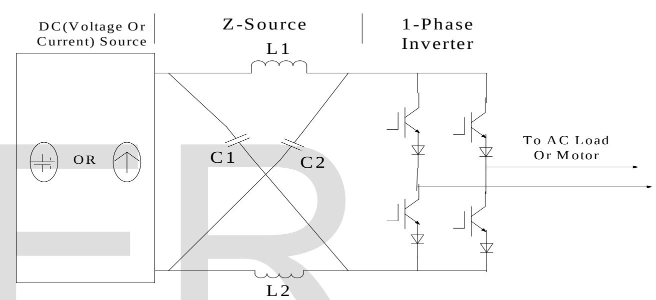

Fig.1. Z-Source inverter structure

3 Z-Source Inverter Analysis

Fig. 2 shows the equivalent circuit of Z-Source inverter in the active state which be actives as a current source. A dc voltage source Vdc is input power source and applied to the Z Source inverter through reverse blocking diode D. All traditional PWM techniques are applicable for Z-Source inverter. During the shoot-through time (T_0) the DC link voltage Vdcl is boosted to a value greater than input voltage, hence input diode will be reverse biased blocking reverse flow of current. The detailed analysis of Z-source inverter is given in [1]. The average dc-link voltage across the inverter is given by

$$V_{dcl} = V_c = \frac{(1-\frac{T_0}{T})}{(1-\frac{2T_0}{T})} V_{dc} \quad (1)$$

Where,

V_{dcl} is the average dc link voltage equal to capacitor voltage V_c , T is a switching period and T_0 is shoot-through time over a switching period. The peak dc-link voltage across the inverter is expressed as

$$V_{dclp} = \frac{T}{T_1 - T_2} V_{dc} = \mathrm{B} V_{dc} \quad (2)$$

Where,

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$$B = \frac{T}{T_1 - T_0} = \frac{1}{1 - \frac{2T_0}{T}} \geq 1 \quad (3)$$

is the boost factor resulting from the shoot-through zero state.

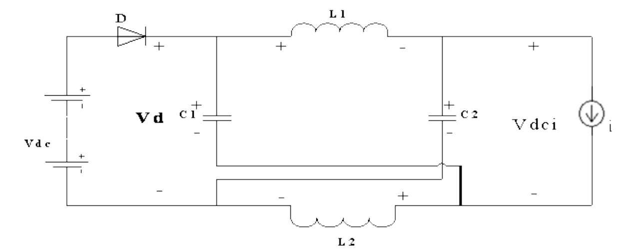

Fig. 1. Equivalent circuit of Z-Source inverter with inverter in active state

The peak dc-link voltage is the equivalent dc-link voltage of the inverter. On the other side, the output peak phase voltage from the inverter can be expressed as;

Vacp = M Vip / 2 (4)

In above equation Vacp is output peak phase voltage, *M* is the modulation index of PWM waveform and Vip is peak dc link voltage across inverter.

Using (2) and (4) peak phase voltage can be expressed as

Vacp = M B Vdc / 2 (5)

For the traditional V-source PWM inverter, the output peak phase voltage is given by

Vacp = M Vdc / 2. (6)

In traditional inverter the output voltage is always less than input dc voltage since, modulation index M is always less than unity. We see from equation (5) that Z-Source inverter the output voltage can be stepped up and down by choosing an appropriate buck–boost factor BB. The buck–boost factor is determined by the modulation index M and boost factor B. For Z-source inverter the boost factor is always greater than or equal to unity. When boost factor is equal to unity the Z source inverter acts like traditional inverter. The boost factor B as expressed in (3) can be controlled by varying shoot through duty cycle T0/T of the inverter PWM input.

4 METHEDOLOGY

The Proposed methodology of project work basically deals with the regulation of speed of induction motor using z-source inverter, especially improvement of transient part. The brief description of proposed methodology is shown in fig.-3 with the help of block diagram representation.

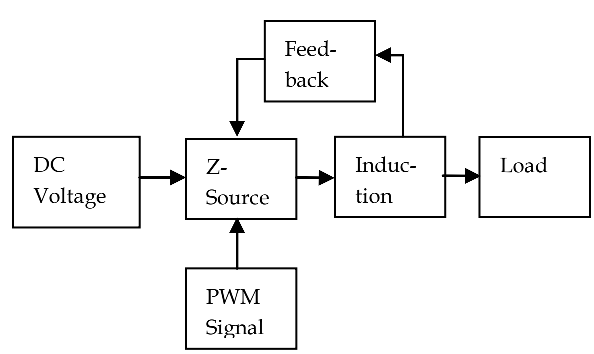

Fig. 3. Block diagram representation of proposed work

Power supply unit consist of a fixed d.c. voltage source along with a freewheeling diode, that provide the smooth voltage requirement also blocks the reverse current flowing from load to source side.

Power supply block is connected to Z source fed inverter the parameter of Z Source (L= 0.0045H, & C=0.0003F,) Match the inverter requirement. Here Universal Bridge is woks as inverter, whose performance can be changed by changing power semiconductor switch (Power MOSFET, IGBT, SCR, Power diode etc).

Input of a three-phase asynchronous machine (wound rotor, squirrel cage or double squirrel cage) modeled in a selectable dq reference frame (rotor, stator, or synchronous). Stator and rotor windings are connected in wyes to an internal neutral point via universal bridge.

One of the Input (feedback input) of motor is constant specified by the 'Constant value' parameter. If 'Constant value' is a vector and 'Interpret vector parameters as 1-D' is on, treat the constant value as a 1-D array. Otherwise, output a matrix with the same dimensions as the constant value. As shown in figure 5 we can choose the output as per our requirement. Here Rotor speed (wm) and electromagnetic torque Te (Nm) are taken for measurement.

5 RESULT

With the help of SIMULINK model, speed of induction motor

TABLE 1
SETTLING TIME V/S FEEDBACK TORQUE FOR REFERENCE SPEED 100 RPM

S.No.	feedback torque (N-m)	Settling time ts (Sec)
1	0	0.8
2	20	0.8
3	40	0.85
4	60	0.9
5	80	0.95
6	100	1.1
7	120	1.2
8	140	1.3
9	160	1.4
10	180	1.7
11	200	2
12	220	2.6
13	240	3.9

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is regulated that is verified by the different SIMULATION results.

The model is tested for different variable conditions via feed-back torque (100 rpm, 120 rpm, & 150 rpm). Table-1 shows the variation of settling time ts for variable feedback torque (N-m) and constant reference condition 100 rpm.

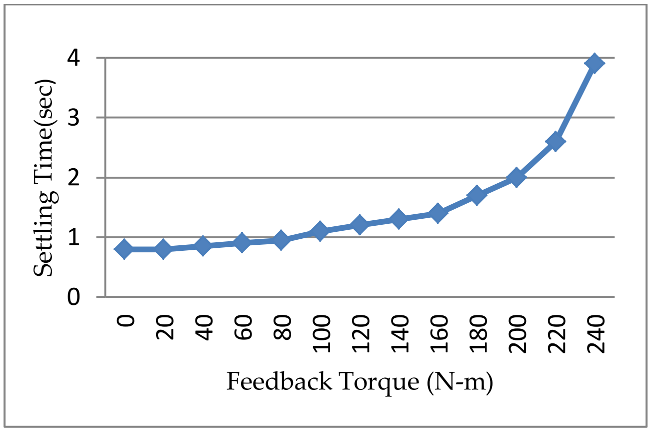

Fig. 4. Settling time V/s feedback torque for reference speed 100 rpm

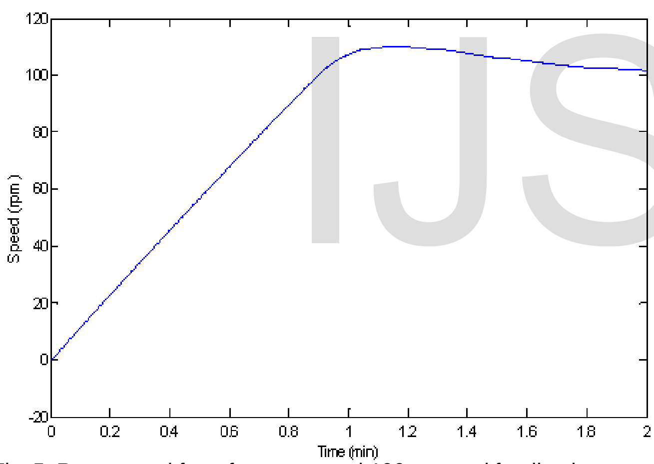

Fig. 5. Rotor speed for reference speed 100 rpm and feedback torque 100 N-m

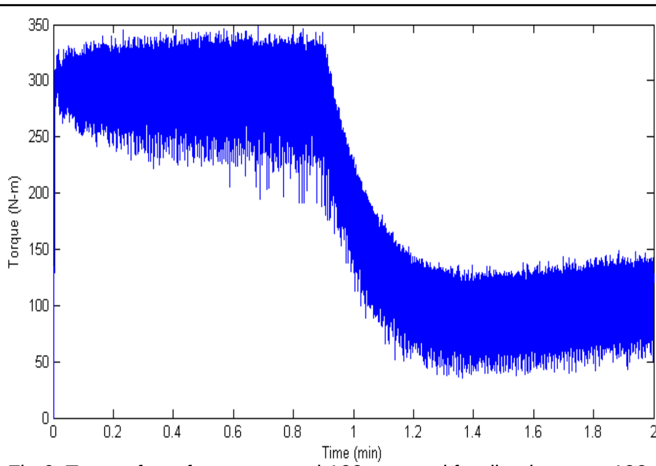

Fig.6. Torque for reference speed 100 rpm and feedback torque 100 N-m

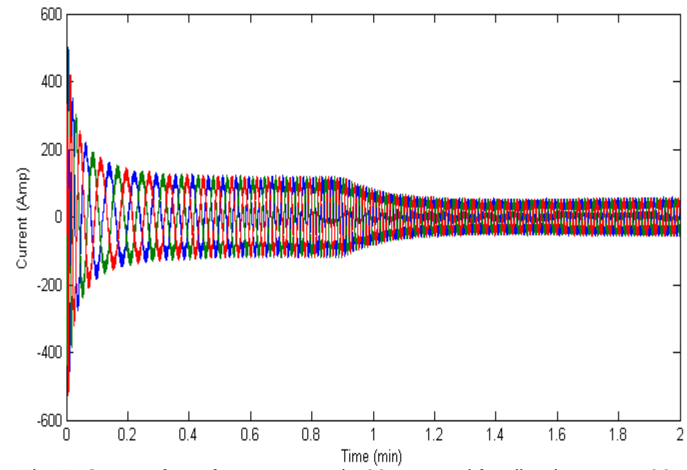

Fig. 7. Current for reference speed 100 rpm and feedback torque 100 N-m

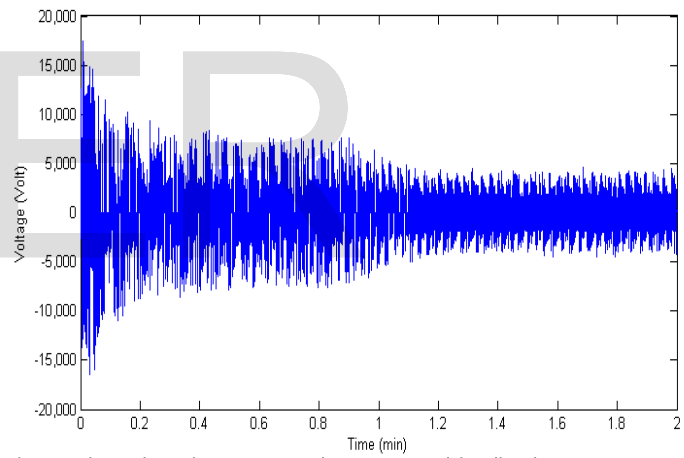

Fig.8. Voltage for reference speed 100 rpm and feedback torque 100 N-m

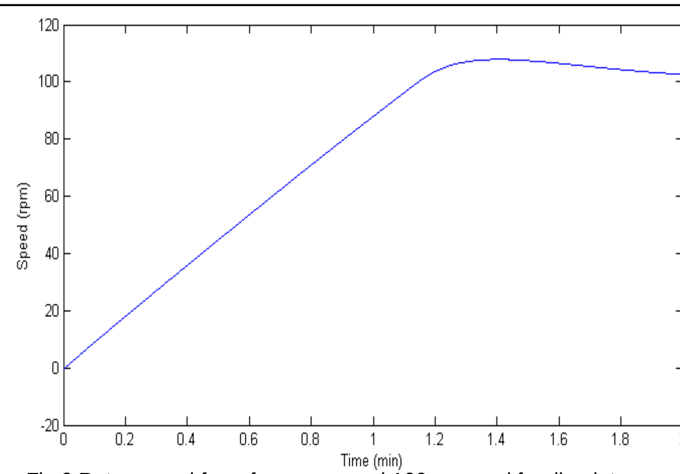

Fig.9.Rotor speed for reference speed 100 rpm and feedback torque 140 N-m

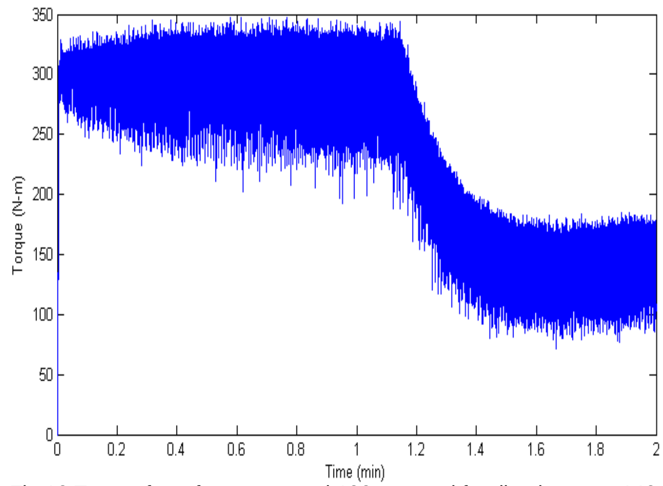

Fig.10.Torque for reference speed 100 rpm and feedback torque 140 N-m

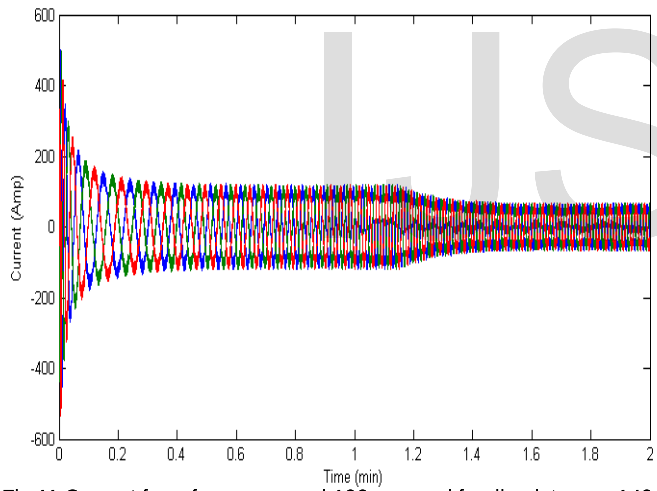

Fig.11.Current for reference speed 100 rpm and feedback torque 140 N-m

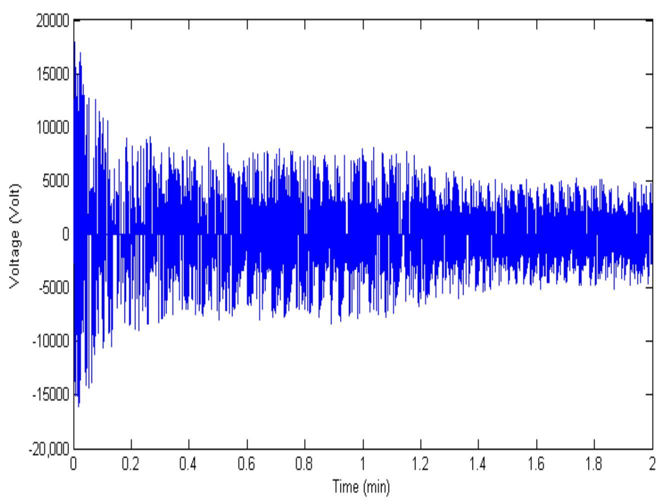

Fig.12.Voltage for reference speed 100 rpm and feedback torque 140 N-m

From the plot fig. 5 to fig. 12 it is clear that the speed response of developed speed controller based on Z source inverter consists transient and steady state part, Voltage V_{ab}, current I_{abc} and internally generated electromagnetic torque.

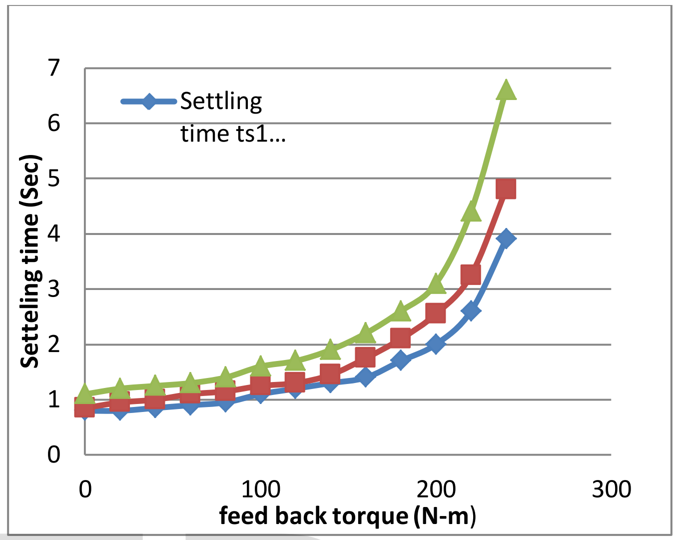

Fig.13. Settling time V/s feedback torque for different reference speed (100, 120, 150 rpm)

6 Conclusion

For the efficient speed regulation most important requirement are

a) Speed response curve must contain stable transient and steady state part and
b) Most important requirement is reduction in settling time.

In addition to this, it is also observable that the speed regulation of devolved technique depends on the value of feedback torque supplied to induction motor.
The figure 5, 9 it is clear that, if the feedback torque increases the settling time also increases. .
In the section-5, a stastitatical analysis is also presented with the help of table-1.Table shows that with reference to feedback torque for induction motor the speed of the motor increases, in that case our aim is to keep the speed of motor constant to increased amount of speed, so that we can have sooth speed characteristics for motor.

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