Eng. & Tech. Journal, Vol.28, No.6, 2010

Design And Implementation of Intelligent Soft- Start Controller For Induction Motor Controlled By VSI

Dr.K.S.Krikor * & A.J.Al-Shammerie*

Received on:27/1/2009
Accepted on:5/11/2009

Abstract

This paper presents a practical implementation of the Fuzzy logic control to an electrical drive system. The hardware control circuits are divided into two groups, the first one is to determine the suitable trigger angle to the load according to their windings resistance circuit. The second is to monitor the motor operation and runs in order to compensate the trigger angle value when any disturbances occur at the motor. The soft starters use the current through the stator winding of the motor as feedback, in which the voltage is adjusted through the setting of the IGBT firing angle. The feasibility and effectiveness of the control scheme are experimentally demonstrated and the results are compared with the conventional soft starter controller in dynamic responses of the closed-loop drive system.

تصميم وتنفيذ مسيطر بدء تشغيل سلس وذكي للمحرك الحثي مسيطر عليه بواسطة عاكس متغير السرعة

الخلاصة

هذا البحث يقدم التنفيذ العملي للسيطرة بالمنطق المضبب لمنظومة الإدارة الكهربائية .دوائر السيطرة تنقسم الى مجموعتين : الأولى لتحديد زاوية الأولية الملائمة للحمل وذلك اعتمادا على مقاومة الملفات الرئيسية للمحرك والثانية لمراقبة عمل واشتغال المحرك من اجل تعويض قيم زاوية القدح عندما يتعرض المحرك الى أي اضطراب خارجي .

البادئ السلس يستخدم التيار المار في مقاومة ملفات المحرك الرئيسية كتغذية عكسية وفيها يتم التحكم في الفولتية من خلال ضبط زاوية القدح لترانزستورات القدرة نوع IGBT.

ملائمة وفعالية مخططات السيطرة قد اظهرت مختبريا وقورنت النتائج مع مسيطر تقليدي في الاستجابات الديناميكية لمنظومة الإدارة بالحلقة المغلقة.

1.Introduction

Three phase asynchronous motors are widely used in industry applications due to their features of low cost, high reliability and less maintenance. But during the starting, the line current of the motor can be of 5-7 times larger than that in the normal operation and the starting torque can be 2 times larger than that in the normal operation. The big starting current will cause power voltage drop and influence the normal operation of other equipment connected in the same power line, and even cause the electrical network to lose stability [1]. 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

* Electromechanical Engineering Department, University of Technology /Baghdad

https://doi.org/10.30684/etj.28.6.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

of belts, gear boxes, chain drives, motor bearings, and shafts [2].Smooth acceleration reduces also stress on the electrical supply due to high starting currents meeting utility requirements for reduced voltage starting and eliminating voltage [3].It reduces also the shock on the driven load due to high starting torque [4], 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 [5].One of the control techniques is the fuzzy logic control technique, due to its great adaptation and flexibility for different operation condition of the system in general,[2]. The fuzzy logic is a technique based on rules that will define the controlled system operation. In the Present work, design of a FL controller experimental application to an electrical drive system is presented.

2. Hardware System Implementation

There are essentially two methods for implementation of fuzzy control .The first involves rigorous mathematical computation for fuzzification, evaluation of control rules, and defuzzification in real time. This is generally a method of efficient C program which is normally developed with the help of a fuzzy logic tool, such as the fuzzy logic toolbox in the MATLAB environment. The program is compiled and the object program is loaded in a DSP (Digital Signal Processor) for execution. The second method is the look-up table method ,where all the input /output static mapping computation fuzzification ,evaluation of control rules, and defuzzification is done ahead of time and stored in the form of large look-up table for real time implementation . Instead of one look- up table, there may be hierarchical tables (coarse, medium, and fine).Look- up tables require large amounts of memory for precision control, but their execution may be fast. In the proposed controller system shown in Fig.(1)there are two fuzzy controllers(one operate always) , the first represent (FLC-1) is called Initial Soft Starting Fuzzy Controller which searches the optimum value of trigger angle that is suitable to the motor rating that connected to over all system. The other controller (FLC-2) is called Tracking Soft Start Fuzzy Control to observe the operation system from any disturbances short/ open of any wire of the3-phase source such as speed variation.The block diagram of the controller (Fig.1) contains four main blocks: Rectifier bridge and filter to give a suitable dc voltage, inverter which is implemented by IGBT block, PWM driver which is implemented by a Random access memory (RAM) containing the sampled values of a standard amplitude, sinewave at equal intervals of its argument. This is scanned by the address counter which can be driven at a variable frequency, which determines the output frequency. Each output pulse width sample is proportional to the product of the instantaneous sinewave value and an amplitude demand signal V_d. This is achieved by digital multiplication, the output pulse width being generated by a fixed rate clock driving a counter from zero up to the value at the output of the multiplier, and fuzzy control: The basic configuration of Fuzzy Logic Controller (FLC) consists of four main parts: (i) Fuzzification, where values of input variables are measured and a scale mapping that transforms the range of values of input variables into corresponding universe of discourse is performed then performs the function of fuzzification that converts input into suitable linguistic values, which may be, viewed labels of fuzzy sets. (ii) Knowledge Base consists of data base and linguistic control rule base.

The database provides necessary definitions, which are used to define linguistic control rules and fuzzy data, manipulation in an FLC. The rule base characterizes the control goals and control policy of the domain experts by means of set of Linguistic control rules. (iii) The Decision Making Logic, it has the capability of simulating human decision making based on fuzzy concepts and of inferring fuzzy control actions employing fuzzy implication and the rules of inference in fuzzy logic. (iv) The Defuzzification, a scale mapping which converts the range of values of input variables into corresponding universe of discourse. The block diagram of the controller (Fig.1) contains four main blocks: Rectifier bridge and filter to give a suitable dc voltage, inverter which is implemented by IGBT block, PWM driver which is implemented by a Random access memory (RAM) containing the sampled values of a standard amplitude, sinewave at equal intervals of its argument. This is scanned by the address counter which can be driven at a variable frequency, which determines the output frequency. Each output pulse width sample is proportional to the product of the instantaneous sinewave value and an amplitude demand signal V_d. This is achieved by digital multiplication, the output pulse width being generated by a fixed rate clock driving a counter from zero up to the value at the output of the multiplier, and fuzzy control: The basic configuration of Fuzzy Logic Controller (FLC) consists of four main parts: (i) Fuzzification, where values of input variables are measured and a scale mapping that transforms the range of values of input variables into corresponding universe of discourse is performed then performs the function of fuzzification that converts input into suitable linguistic values, which may be, viewed labels of fuzzy sets. (ii) Knowledge Base consists of data base and linguistic control rule base. The database provides necessary definitions, which are used to define linguistic control rules and fuzzy data, manipulation in an FLC. The rule base characterizes the control goals and control policy of the domain experts by means of set of Linguistic control rules. (iii) The Decision Making Logic, it has the capability of simulating human decision making based on fuzzy concepts and of inferring fuzzy control actions employing fuzzy implication and the rules of inference in fuzzy logic. (iv) The Defuzzification, a scale mapping which converts the range of values of input variables into corresponding universe of discourse The basic operation of proposed work is the estimation of the stator resistance is done as indication for motor rating which provide an overload protection for the system. When the motor start, the controllable power supply sent power signal to motor winding in order to determine the retracted current, this current is input to two circuits one to check the motor rating in working range of drive, and the other is input to initial fuzzy control with same signal measured after time delay as crisp input to the Fuzzifier unit with, each signal fed from bank RAM consist of 8-RAM stored the sides triangular membership function. The RAM has 243 location is divided at 60 for each side of triangular, Fig. (2) shows an example of fuzzification. A crisp input of -2 is shown for which two sets have non-zero. membership: LN and SN., the membership of LN is about 0.2 while that of SN is about 0.7 .thus , given the crisp input -2 , the fuzzy variables given by the set of memberships: [0.3 0.7 0 0 0].Signal amplitude represents address to out the memory contain that store previously according to motor parameters which shown in appendix

The input signals to fuzzy circuit represented by equation:

$$\Delta I = I(t) - I(t-1) \qquad \ldots\ldots(1)$$

Where: I(t): is direct signal measured at real time, I (t-1): is indirect signal.

3. Results

The proposed system shown Fig.(3) has specification 3A max , 380V, 1KW was tested with induction motor has specification shown in Table(1) and the results are compared with the conventional controller at no-load and 0.7 Nm load. When the motor is run at 1500 rpm with no-load and 1450 when loaded at 0.7 N.m respectively. Figs 6,7 show the output voltage waveform of conventional controller when the motor are unloaded and loaded at 0.7 Nm, as comparison between two cases we can see the waveforms of proposed controller are approaching from sinusoidal and contain very low ripple.

Figs. (8) and (9) show the starting current waveform of the proposed and conventional controllers at no load. It is clear from the results shown in Fig (8) that the current is gradually increased from zero to (0.102A) at (1) sec and drops to steady state current at (0.1A) at (1.5) sec. In this figure the zero current disappears and very low overshoot it occurs. That means that the proposed controller is working in real-time to estimate the trigger angle value which allows appearing the current increases gradually.

Figs (10),(11) show the starting current waveforms of the proposed and conventional controllers respectively, when the load is increased to (0.7N.m). The performance of the controller is stable and in constancy with the output waveform of the pervious case. This indicates the high response of the proposed controller to load change.

4.Conclusions

The hardware implementation of intelligent controller is done according to the schematic representation as shown in Fig(1) this scheme is superior over other schemes since it has on-line adaptive parameter setting capability and also the ability to start any motor at any load, and it's fully tested in laboratory and gave good results. The proposed controller results compared with conventional controller results which have same parameters, and with same load cases. shown to be superior. This controller has the following advantages:

1- Basic experiments on fuzzy logic and fuzzy control can easily build up.

2-Low cost using the available IC's in the market.
3-Analog hardware rule evaluation.
4-High processing speeds.
5- The control way is simple. The firing pulses are not synchronous with the ac –mains. The inrush current and mechanical impact can be avoided, and enough torque for start-up can be obtained quickly. In addition, the torque oscillation is avoided during the soft-start process. So, a kind of intelligent soft-start controller for induction motor is achieved, which provides a valuable reference for the designs of similar control systems. This paper presents a novel fuzzy soft start scheme based on winding resistance of motor connected.

5. References

[1] H. A. Ashour and R. A. Ibrahim” Implementation and Analysis of Microcontroller Based Soft Starters for Three Phase Induction Motors” IEEE, 2007.

[2]R. F. McElveen and M. K. Toney, “Starting high-inertia loads,” IEEE Trans. Ind. Appl., vol. 37, no. 1, pp. 137–144, Jan./Feb. 2001 .

[3] J. Nevelsteen and H. Aragon, “Starting of large motors—Methods and economics,” IEEE Trans. Ind. Appl., vol. 25, no. 6, pp. 1012–1018, Nov./Dec. 1989.

[4] G. Zenginobuz, I. Çadirci, M. Ermis, and C. Barlak, “Soft starting of large induction motors at constant current with minimized starting torque pulsations,” *IEEE Trans. Ind. Appl.*, vol. 37, no. 5, pp. 137–144,. 2001.

[5]F. Blaabjerg, J. K. Pedersen, S. Rise, H. H. Hassen, and A. M. Trzynadlowski, “Can soft-starters help save energy?, *IEEE Ind. Appl. Mag.*, vol. 3, no. 5, pp. 56–66,. 1997.

Table (1) The specifications of the squirrel cage induction motor parameters

Type	3-phase Y -connected
Rated power	/3 hp1
Rated voltage	380 V
rated current	1 A
Rated frequency	50Hz
Rated speed	1500 rpm
Number of poles	4

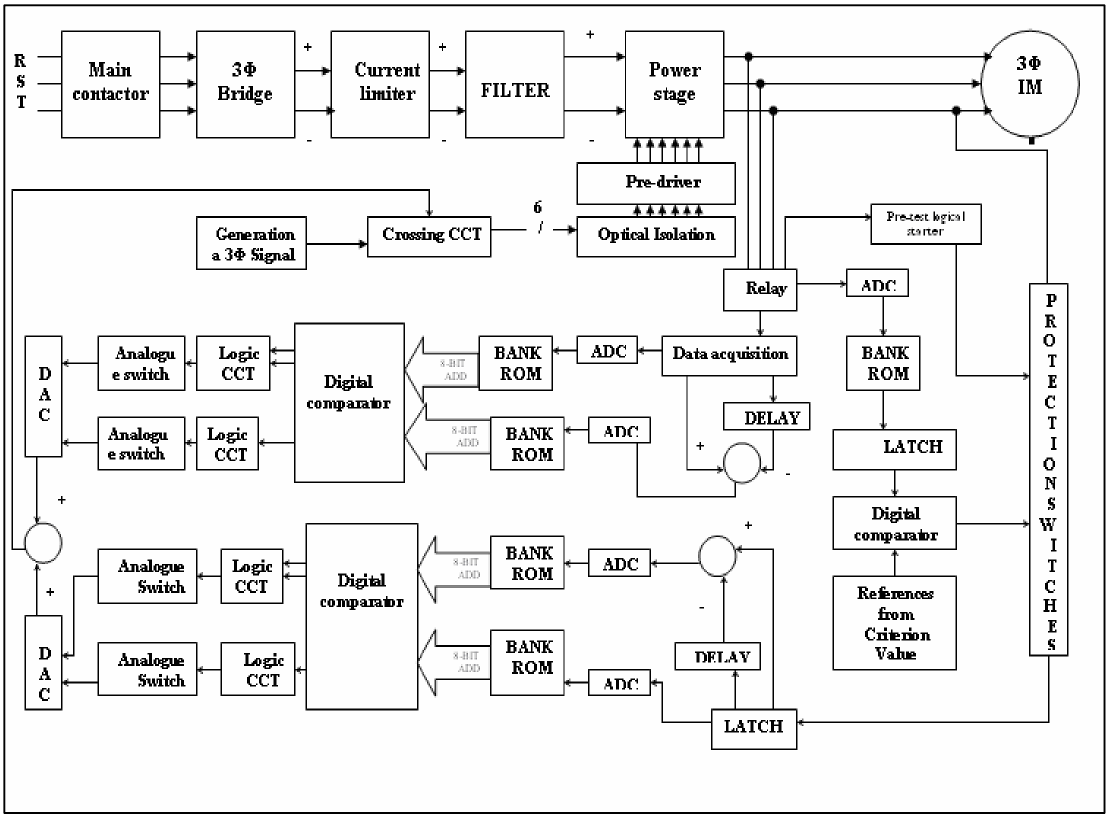

Figure (1) Block diagram of proposed system

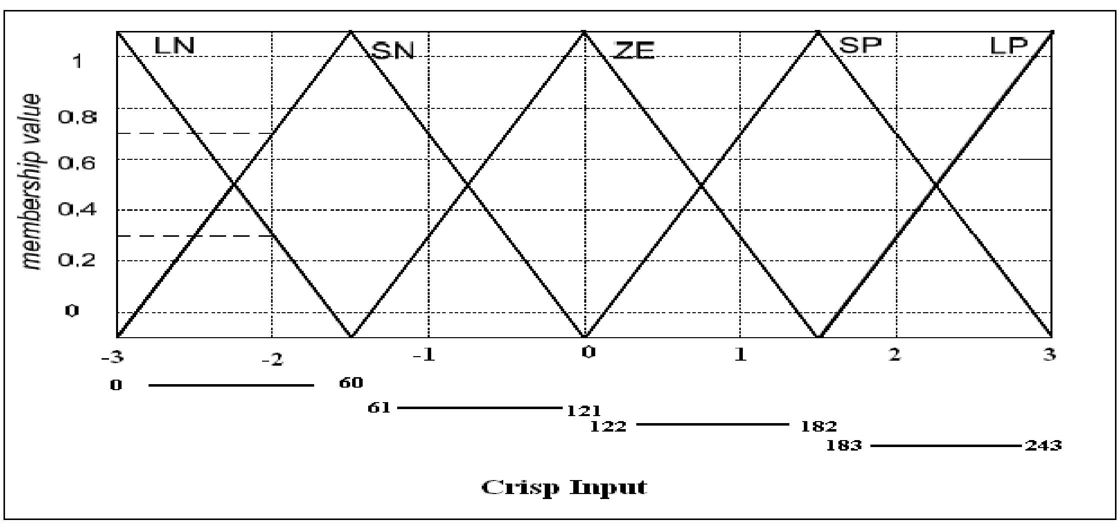

Figure (2) fuzzy set labeling

Figure (3) The photograph of the experimental setup

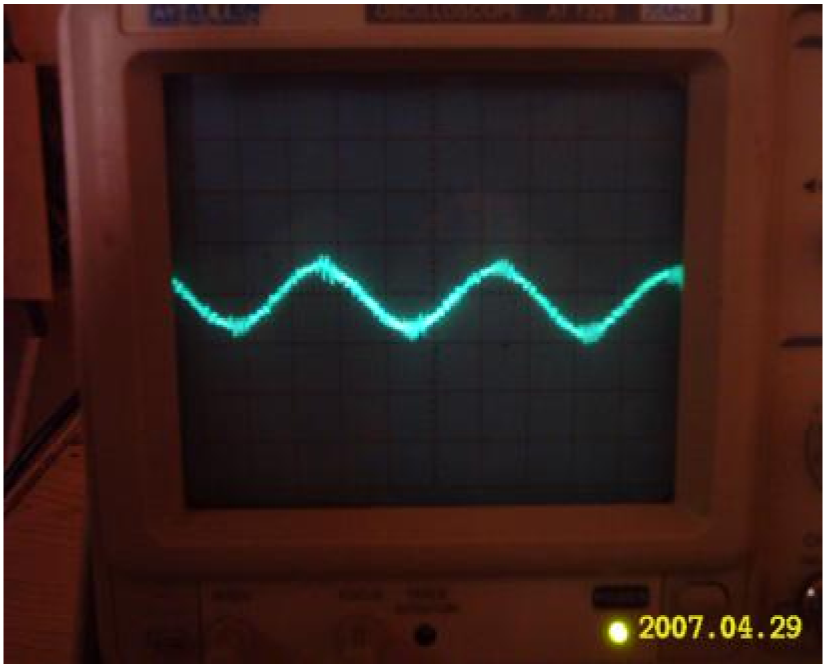

Figure (4) Line current waveform of proposed controller at no-load

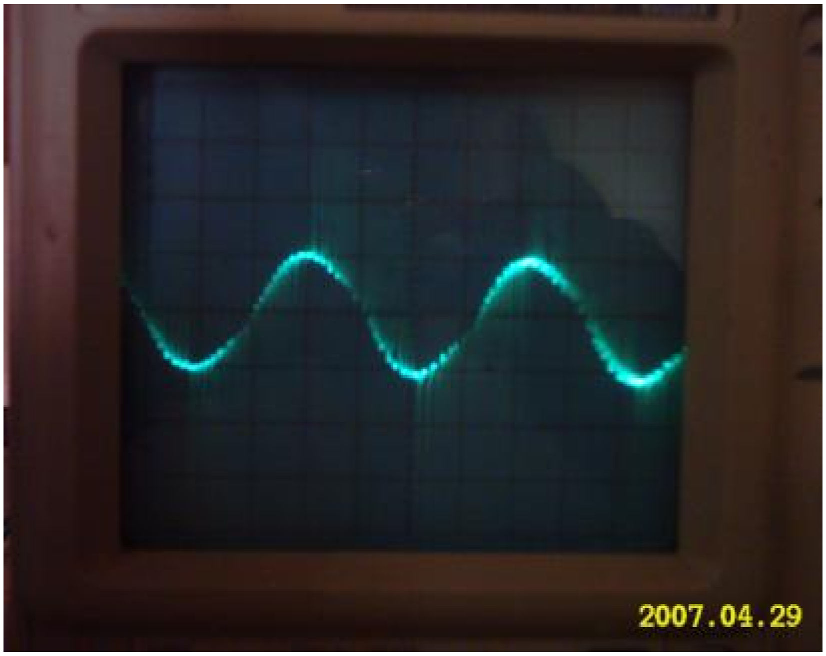

Figure (5) Line current waveform of conventional controller at no- load

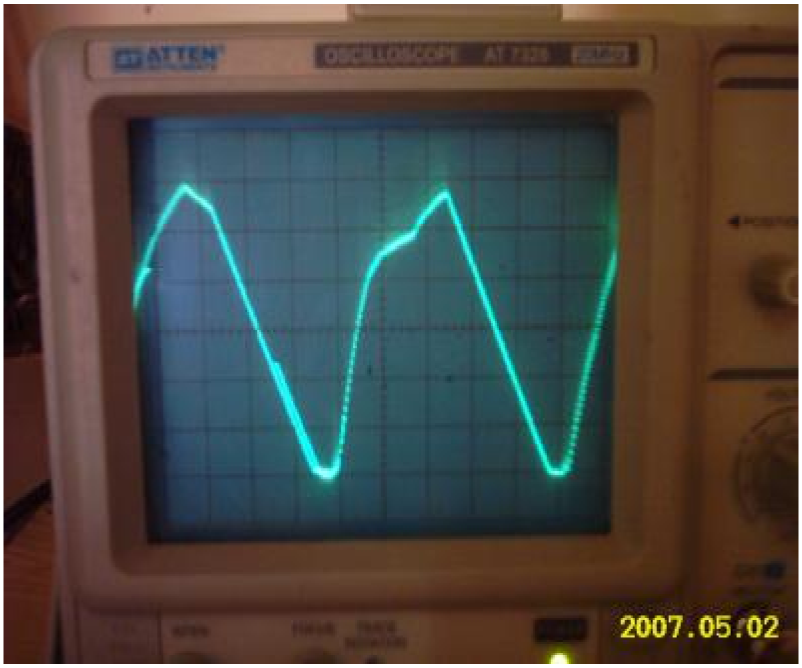

Figure (6) Line current waveform of proposed controller at 0.7 Nm load

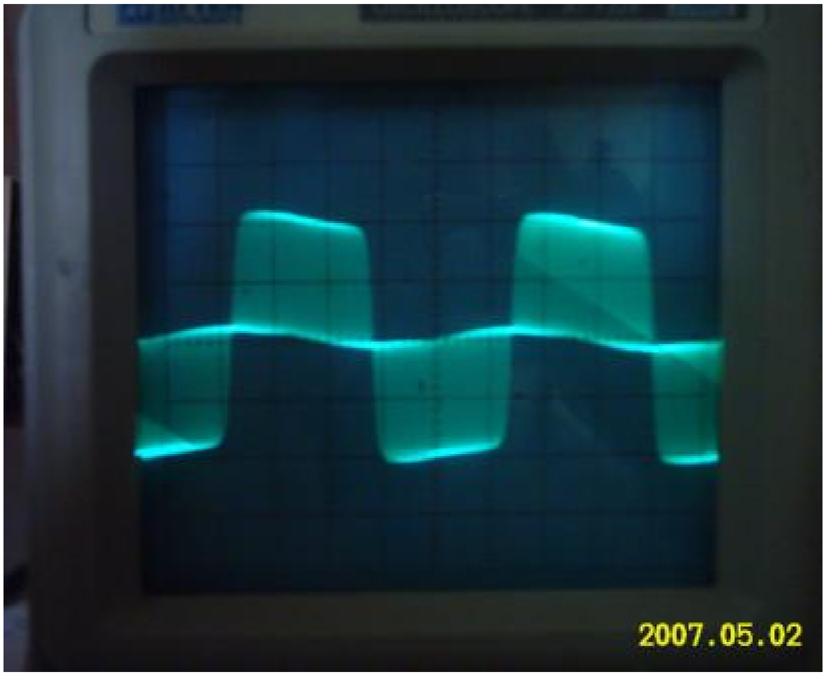

Figure (7) Line current waveform of conventional controller at 0.7 Nm load

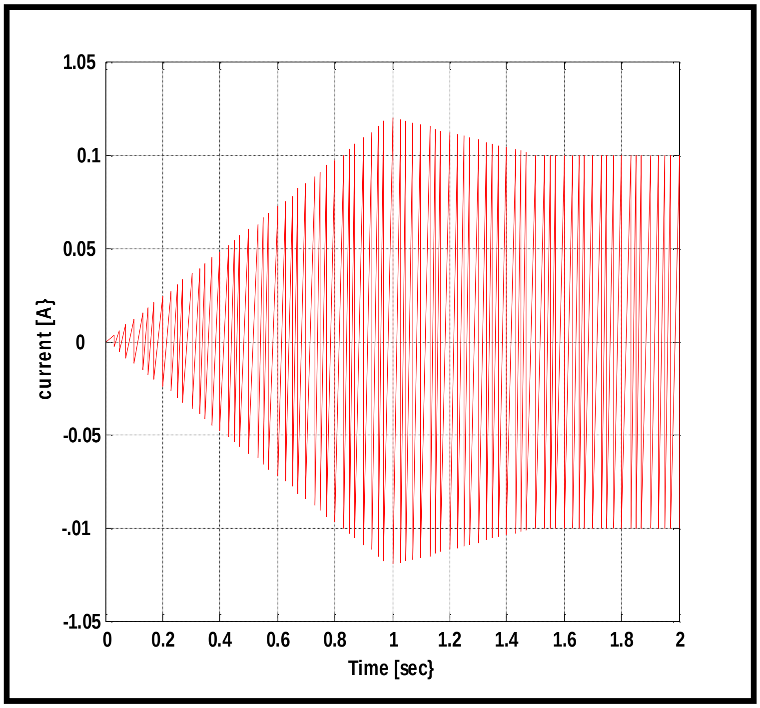

Figure (8) Starting current response of proposed soft start controller at no-load

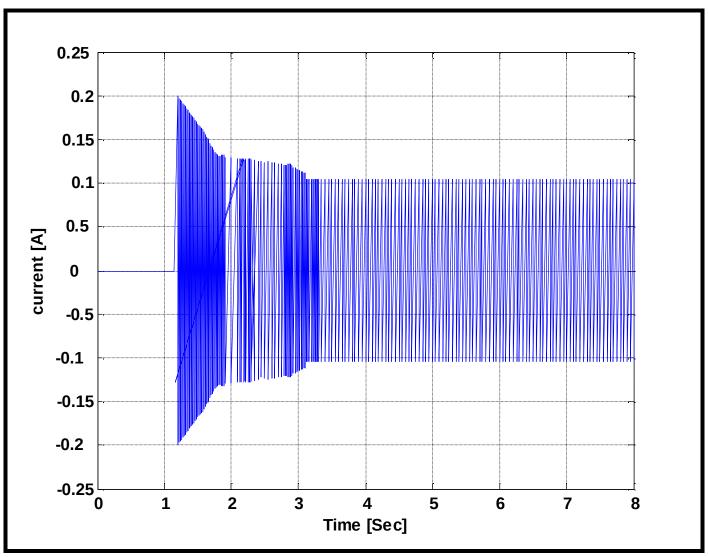

Figure (9) Starting current response of conventional soft start controller at no-load

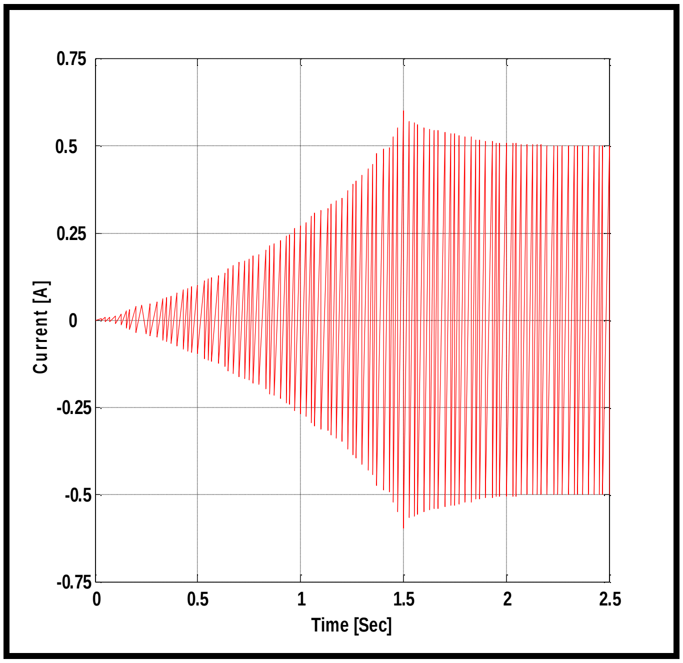

Figure (10) Starting current response of proposed soft start controller at 0.7 Nm load

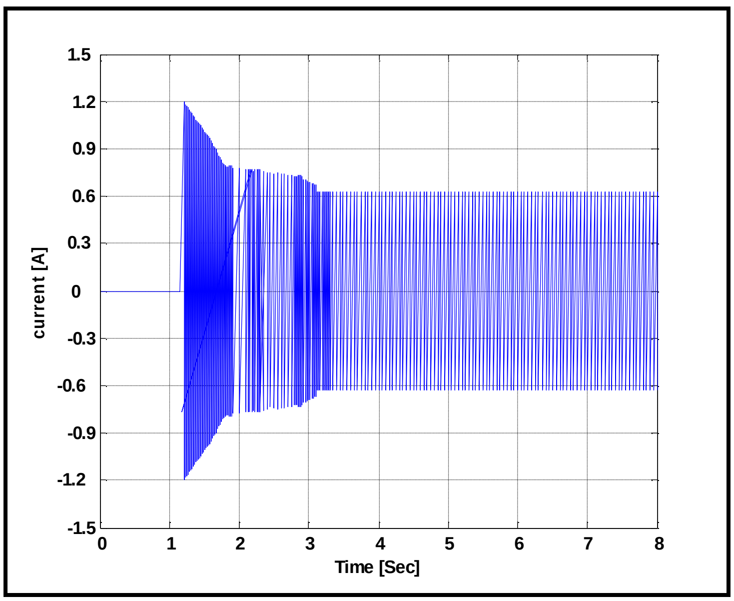

Figure (11) Starting current response of conventional soft start controller at 0.7 Nm load