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SCR Based Soft Starter for Three Phase Induction Motor

Anuja M. Kadam, Mayuri D. Bhosale, Rushikesh D. Thorat,

Chaitanya S. Salunkhe, Prof. Jamdade A. S.

Electrical Engineering Department,

Dnyanshree Institute of Engineering & Technology, Sajjangad Road, Satara

1.Abstract: This paper describes the soft and smooth start to a three phase induction motor. The three phase induction motor during the initial starting condition draws up much higher current than its capacity and the motor instantly reaches the full speed. This results in a mechanical jerk and high electrical stress on the windings of the motor. Sometimes the windings may get burnt. The prototype have been developed to give a soft start to the induction motor based on the SCR firing triggered by heavily delayed firing angle during starting and then gradually reducing the delay till it reaches zero voltage triggering. This results in low voltage during start and then gradually to full voltage. Thus the motor starts slowly and then slowly picks up to full speed. The working prototype consists of a six anti-parallel SCRs, two for each phase, the output of which is connected to a set of lamps representing the coils of a 3 phase induction motor, capacitors, comparators, opto-isolators to trigger the SCRs. This can be enhanced by using IGBTs in place of SCRs with PWM control to reduce harmonic distortions often encountered in SCR triggering mechanism for future scope. The implementation of hardware model has been discussed in this paper.

Keywords: Firing angle delay, Motor current control, Opto-couplers, Opto-isolators, SCR triggering, Zero voltage triggering.

2.Introduction

Three phase induction motors are considered the universal work horses of industry, converting up to 80% of all electrical power into mechanical energy and cover up many heavy industrial applications such as fans, blowers, compressors, mixers, conveyors…etc. Controlling the starting performance of three phase induction motors have always been the interest of many researchers, to develop varies techniques in order to control the starting transients associated with induction motors. The need for reduced starting current condition not only reduces the stresses on the power utility, but also decreases the stresses on the motor and driven equipment, reduces overload and under voltage relay trips and increases the number of start/stop times of the motor itself per day. Many methods have been introduced for starting induction motors. Basically, they can be divided into two major groups; electromechanical starters and electronic starters. The name electromechanical starters from the fact that they employ electromechanical contactors, relays, resistances and transformers for offering reduced voltage starting. Under this type of starters, methods such as direct online starting (DOL), star-delta starting, stator resistance starting and autotransformer starting are listed. As for the electronic starters, there are the AC voltage controller starters and V/F starters. Choosing the type of motor starter for each application depends on the motor characteristics, available space, load torque requirements and overall cost. This paper introduces soft starting techniques. The project is designed to provide a soft and smooth start to a 3 phase induction motor. The three phase induction motor during the initial starting condition draws up much higher current than its capacity and the motor instantly reaches the full speed. This results in a mechanical jerk and high electrical stress on the windings of the motor. Sometimes the windings may get burnt. The induction motor should start smoothly and gradually catch up the speed for a safer operation. This project is designed to give a soft start to the induction motor based on the SCR firing triggered by heavily delayed firing angle during starting and then gradually reducing the delay till it reaches zero voltage triggering. This results in low voltage during start and then gradually to full voltage. Thus the motor starts slowly and then slowly picks up to full speed.

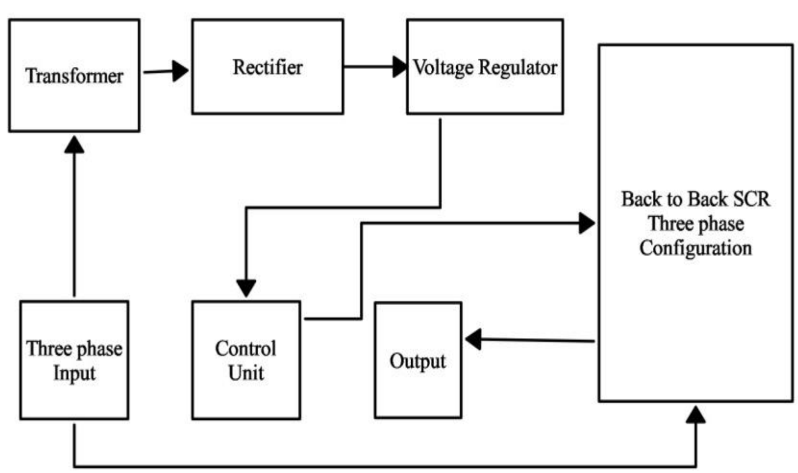

Fig.2.1 Block Diagram of SCR based soft starter for three phase induction motor

Three phase AC supply is given to soft starter to perform its operation. Three step-down transformers are used to step down voltage for each phase; three bridge rectifiers are connected to convert AC to DC. Since we need pure DC as well as pulsating DC, The AC supply is not constant always so a voltage regulator is employed to get the fixed DC supply

The circuit consists of six-anti-parallel or back to back SCRs connected in each series with an induction motor to the mains supply, where in two for each phase is used. Opto-coupler is connected to trigger the back-to-back SCRs with isolation from the controlling section. During the start, the firing angle is heavily delayed by receiving delayed triggering pulses from the operational amplifier. Soft and smooth starters provide smooth acceleration of rotor of three phase induction motor. Reduced voltage starting reduces high amount of starting torque applied on the shaft and therefore eliminates the shock on the driven load. An instantaneous high amount of starting torque can cause a jolt on the conveyor which can damage products, pump cavitation and water hammer in pipes. Therefore, a soft starter ramps up the voltage applied to the motor from the initial voltage to the full voltage. The voltage is initially kept low to avoid sudden jerks during the start. The voltage and torque increases gradually so that the induction motor starts to accelerate. This ramp up voltage provides sufficient torque for the load to accelerate gradually and hence mechanical and electrical shocks are minimized from the system, The voltage supplied to stator windings are adjustable and it has ramp characteristics.

2.1 SCR Based Soft Starter :

A soft starter is another form of reduced voltage starter for A.C. induction motors. The soft starter is similar to a primary resistance or primary reactance starter in that it is in series with the supply to the motor . The current into the starter equals the current out. The soft starter employs solid state devices to control the current flow and therefore the voltage applied to the motor. In theory, soft starters can be connected in series with the line voltage applied to the motor, or can be connected inside the delta loop of a delta connected motor, controlling the voltage applied to each winding

3.System design

The 3 phase induction motor should not be given full voltage at a time of starting, because in off condition the back EMF of the motor is very low, So initially it draws high current. To start the motor with low current, two SCR'S are connected back to back in each phase and are triggered slowly initially by delayed firing angle and gradually the triggering pulse is increased by decreasing the delay in firing angle till zero delay so that motor current slowly rises without any excessive current during the starting of the motor.

To trigger the gates of SCRS, the operational amplifiers are used i.e. LM339 and LM324. Lm324 op-amp is configured to get a level voltage comparison at its input that will initially be high and gradually full to zero. To achieve the above operations +12v DC supply is required. So we generate our own DC power supply as follows.

Three step-down transformers are used to step down 230v AC to 12v AC for each phase; three bridge rectifiers are connected to convert 12v AC to DC. Since we need pure DC as well as pulsating DC, a blocking diode is employed after each bridge rectifier to isolate pulsating DC and pure DC. After blocking a filter capacitor is connected to get the pure DC.

The AC supply is not constant always so a 7812 voltage regulator is employed to get the fixed 12v DC supply. A 10uf capacitor is connected at the output of 7812 for stability; a LED with a series resistor 1k is connected to indicate the power. Lets discuss about the ramp generation and level generation for one phase and the same thing is applied for rest 2 phases.

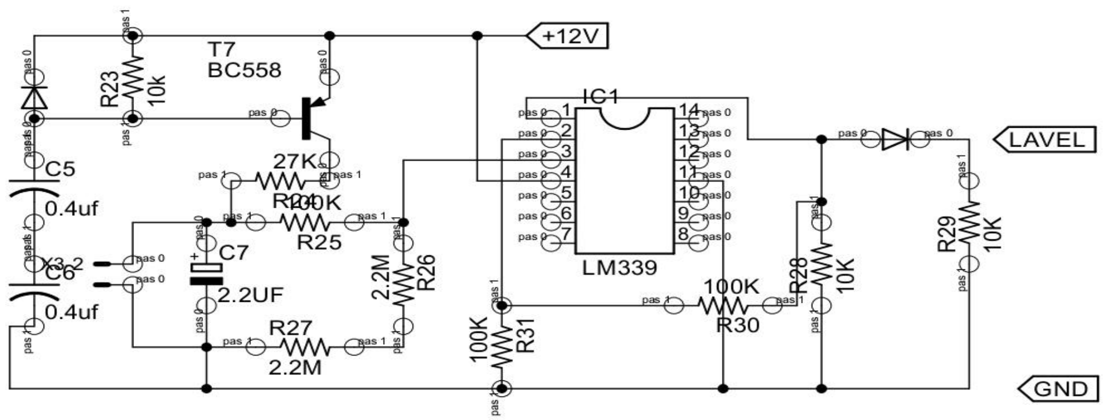

Fig. 3.1

For generating level voltage a p-n-p BC 558 transistor is used whose emitter is connected to the +12v supply and base is connected to a ceramic capacitor 0.4uf and the collector is connected to an electrolytic capacitor via resistor. Initially at the time of switch on the the base of transistor allows current flow from emitter to base and charges the capacitor as well as current flows from emitter to collector and charges capacitor.

When capacitor is fully charged, the base becomes high due to which the current stops flowing from emitter to base and collector. The positive terminal of capacitor is connected to the non-inverting pin of LM324 comparator, the inverting terminal of comparator is fed from a fixed voltage. When the capacitor is charging the voltage at non-inverting terminal is greater than the inverting terminal, hence the output of comparator is high during this time. When the capacitor starts discharging the voltage at the output of comparator also falls gradually because the voltage at non inverting terminal falls lower slowly than the inverting terminal. Hence the level of the voltage is initially high and gradually falls down; this level voltage L is fed to another comparator of Op-amp LM339.

By using LM339 firstly a zero voltage reference is generated as follows. The inverting terminal of the comparator is connected to pulsating DC "P" and the non-inverting terminal is connected to the pure DC of amplitude lesser than the pulsating DC. Hence we get a zero voltage signal "Z" at the output of comparator and it is inverted by transistor and fed to the inverting terminal of another comparator whose non-inverting terminal is being fed from level generator circuit. At the output of transistor an electrolyte capacitor is connected which charges gradually and discharges rapidly, hence a saw tooth or ramp R is achieved.

The ramp and level voltages are fed to the comparator. When the level voltage "L" is high the pulse width of output pulse is more, which is inverted by transistor BC 558 to get small pulse width initially to the Opto LED. As the level voltage falls down the pulse width of the opto LED from the output of transistor increases, hence triggering the gates of the SCRs earlier and finally without any delay while the width is the maximum. Thus the motor starts with low voltage and gradually gets full voltage to avoid sudden inrush of current. Similar delay happens for all the three phases by 3 sets of such circuit.

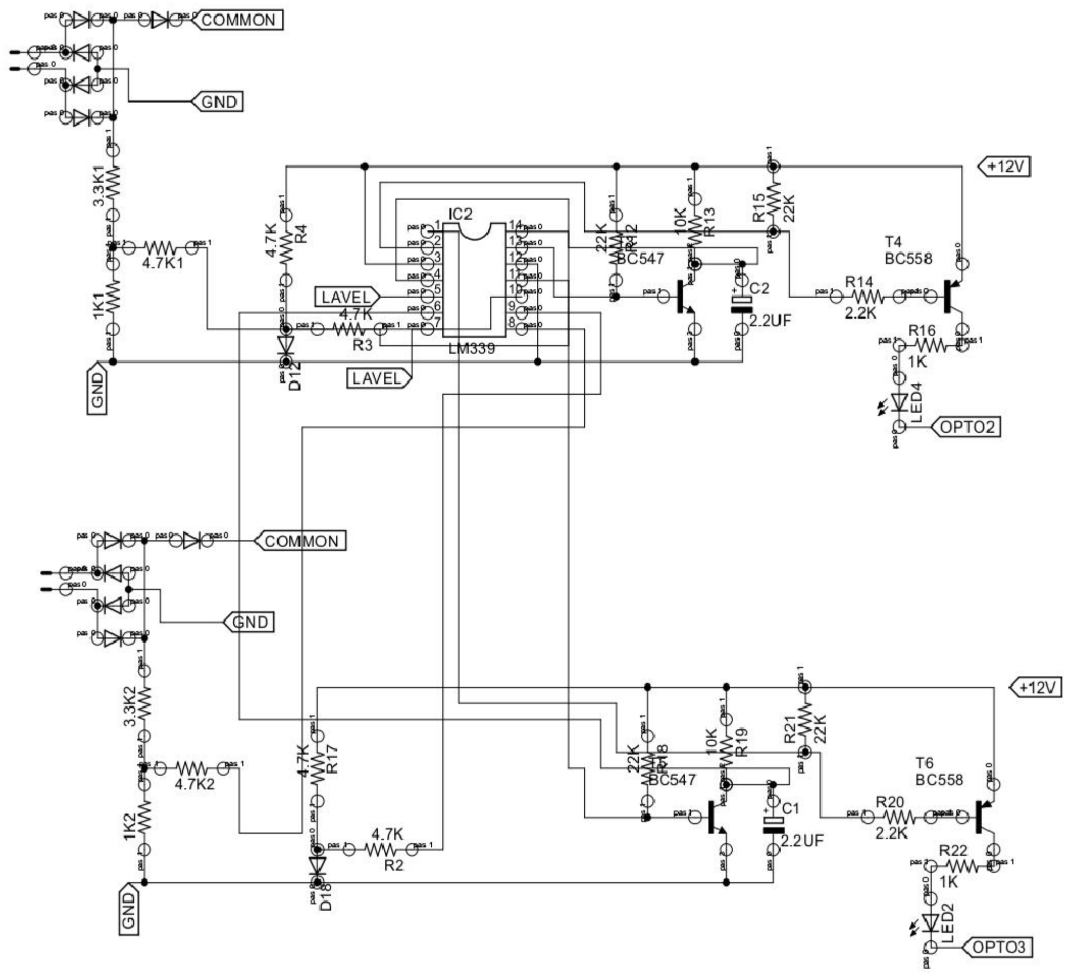

Fig. 3

In each phase two SCR’S are connected back to back and are triggered from Opto-isolators. MOC3021 Opto-isolator is a LED-DIAC combination. Two Opto-isolator input leds are connected in series while their output diac are used for triggering each SCR.

During the positive half cycle of main current, the current flows from phase to the motor through SCR, and SCR is triggered slowly. During negative half cycle flows from motor side to the phase during this time another SCR comes into picture.

Like this other two phases also controlled. Hence we can conclude that the main current is initially low when the SCR is triggered gradually and as the pulse width of triggering pulse increase the main current also increases and full current flows after a very little time delay, hence the motor is protected from initial high current.

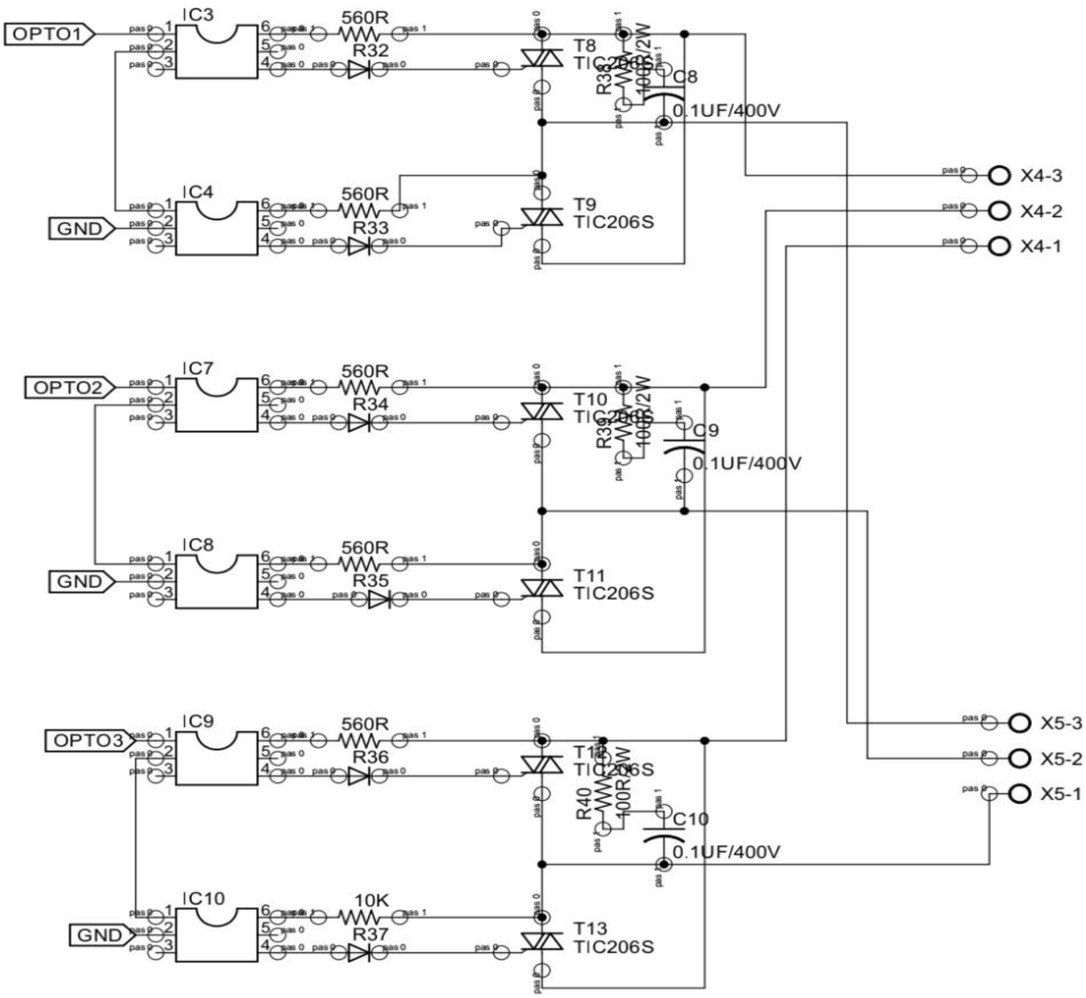

FIG. 3.3

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3.2Simulation

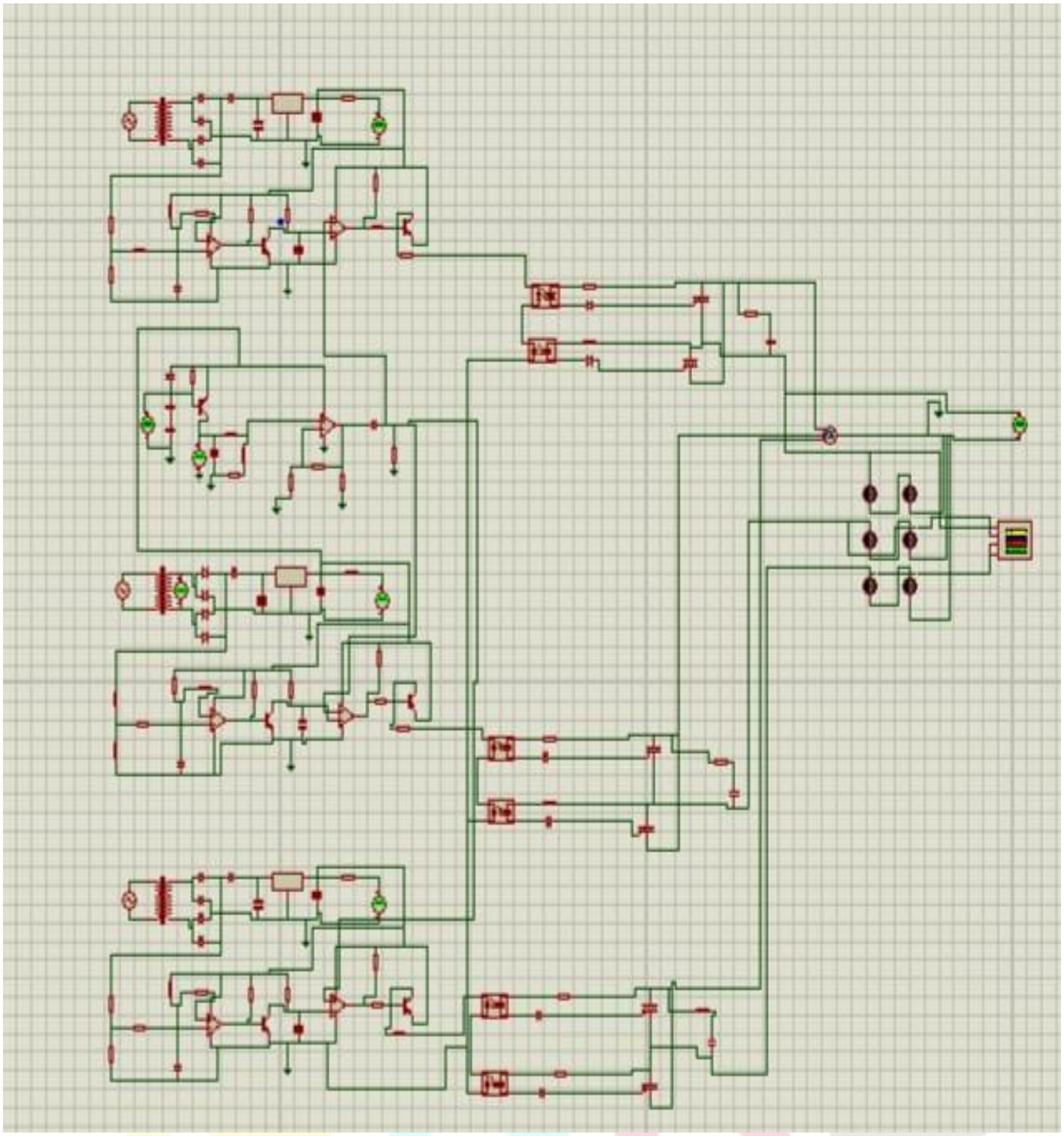

Fig 3.2 Simulation Circuit of SCR Based Soft Sarter for Three phase Induction Motor

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4.Results

This Method of soft starting initially after switching on the triggering is done and this implies the on condition of SCR which are connected anti parallel in each phase. The triggering is done by amplifier triggering method. The current limiting process in the soft starting method is very efficient than that D.O.L. starter and star-delta starter. The amount of limiting current can be vary or adjusted by changing the triggering angle for SCR's.

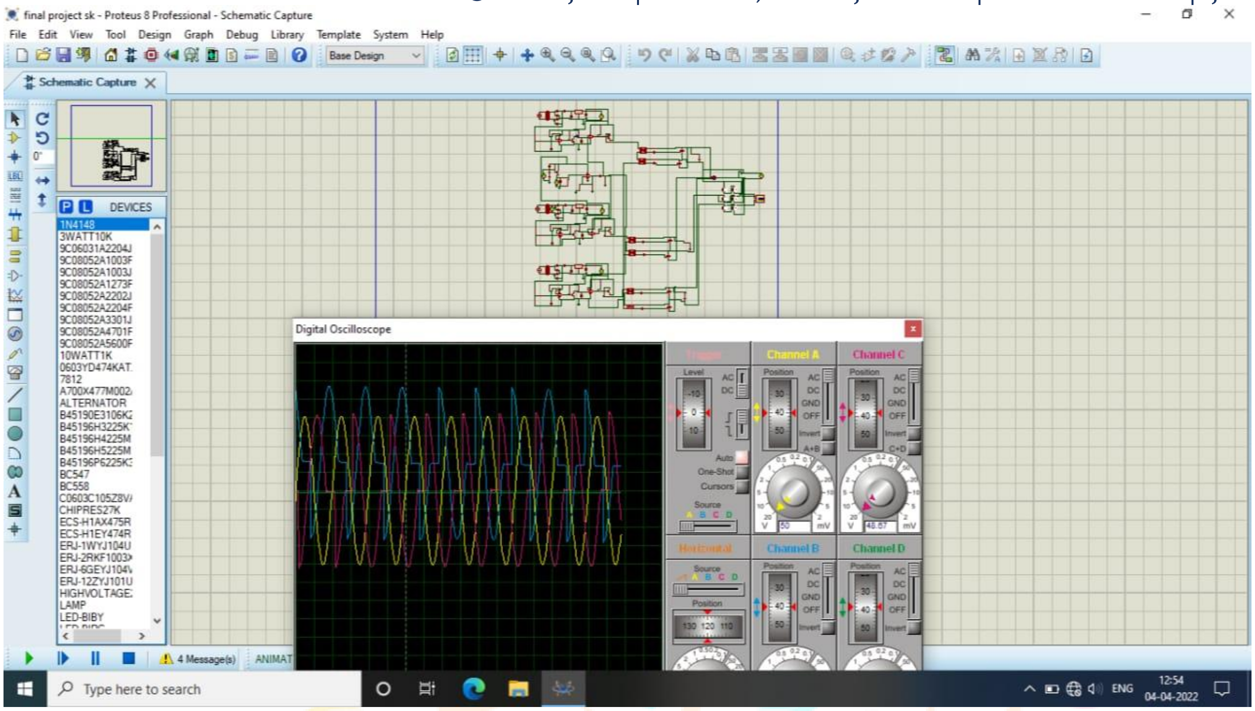

Fig. 4.1 Simulation Result of SCR Based Soft Starter for Three Phase Induction Motor

5.Conclusion and Future Scope

An effective and efficient technique has been presented in this paper which provides reduced voltage and reduced current at starting and at the same time, a control in an electromagnetic torque is also obtained. The motor torque is varied according to load torque and acceleration is maintained constant over the entire starting period with the help of this technique. The proposed approach eliminates shaft torque pulsations at the time of starting. The starting current is reduced significantly with the use of soft-starter circuit. The soft starter also eliminates the starting losses in the motor and hence it results in increased life and increased efficiency of an electric motor. It is found that the heating losses are reduced by 50% when soft-starters are employed during starting of three phase induction motor.

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