SpeedControl of Three Phase Induction Motor

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I. Introduction:

In this project three different control strategies for controlling a three-phase ac chopper under induction motor load have been introduced. These strategies are known as extinction angle control (EAC), modified phase angle control (MPAC), and symmetrical angle control (SAC). These techniques depend on varying the stator ac voltage to control the speed of three-phase induction motor. The system consists of six bidirectional switches. The performance evaluation of the motor under the different switching strategies. The output voltage of proposed strategies will be analyzed by simulation using Matlab and LTspice computer program. The switching signals will be received from the microcontroller.

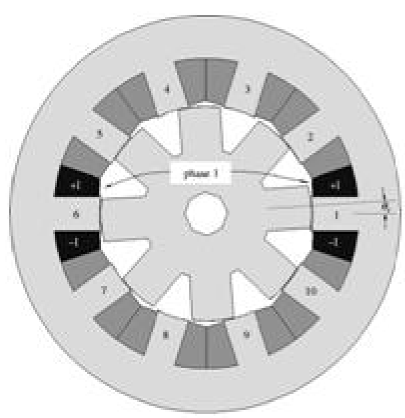
I. Background:

The greatest number of electrical motors manufactured is induction motors. They range from small fractional horsepower (hp) motors to large machines. The cheap robust construction and shunt motor characteristics of induction motor (IM), far outweigh its relatively poor efficiency and power factor in comparison with, for example, the synchronous motor. In size, IM range from tiny fractional (hp) single phase machines used for power record players, fans, pumps and domestic appliances, to large three-phase motors rated at thousands of (hp). The speed of IM is nearly constant dropping only few percent from no load to full load [1].

The main disadvantages of IM are:

- Speed is not easily controlled.
- Starting current may be five to eight times full load current.
- Power factor is low and lagging when the machine is lightly loaded [2].

Like all electrical machines, the induction motor consists of a stator and rotor. The stator of a 3 phase induction motor is built up of sheet steel laminations insulated from each other. Slots are pressed out on the internal periphery of the stator laminations. Three phase armature winding is assembled in these holes. This represents the main winding of the machine and is to be connected to a 3 phase balanced supply.



Note: Phase 1 (stator poles 1 and 6) under excitation

Picture retrieved from Google Images.

When a three-phase supply is connected to a three-phase stator winding, a rotating field is produced which rotates at a synchronous speed, N_s where N_s is given by

$$Ns = \frac{F}{P} * 60$$

where F is the supply frequency and P is the number of pole pairs [3].

Under normal operating conditions, the motor will run at some speed N less than the synchronous speed. N is related to the synchronous speed by the equation.

$$N = (1 - S)\, N_s$$

Where S is a fraction known as the slip and is given by:

$$S = (N_s - N) / N_s$$

Many methods are available for starting three phase induction motors, among of which are:

1) Reduction of supply voltage
2) Adding reactions or resistors in series with the stator windings
3) Adding resistors in series with the rotor windings. This is suitable only for wound rotor motors
4) Y/Δ switch. This is appropriate for motors designed to operate normally as Δ connected

One of the disadvantages of 3 phase induction motors is the difficulty of exerting effective economical wide range speed control on them. The available techniques in this respect are

1) Adding resistances in the rotor circuit
2) Variation of frequency
3) Pole changing
4) Variation of voltage magnitude [2]

II. Problem definition:

Control the speed of the motor at different torque.

III. Solution:

In this project was done to control the speed of the three phase induction. Figure1 shows the simple block diagram for the system. The basic operation mechanisms are that when the series switches are closed the parallel switches are open then the current will be flow from supply to the induction motor.

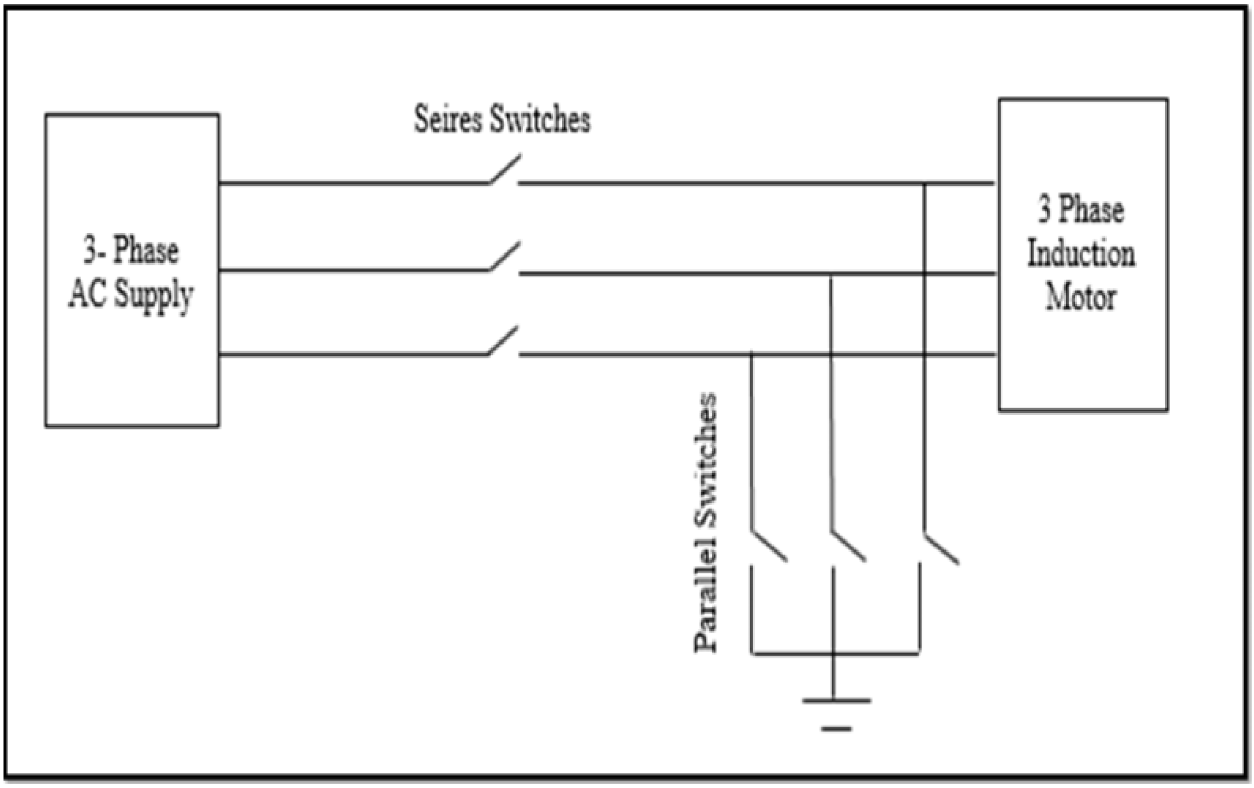


Figure1. Simple block diagram for the system

The first three switches are called series switches and every one of them is connected between the transformer terminal and motor terminal. Another three switches are called parallel switches and every one of them is connected between the motor terminal and the ground.

By dividing the project into these sub system blocks the design can become a simpler project. The project has six switches. Figure.2 Shows one of the switches.

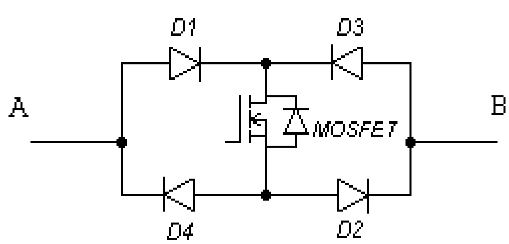


Figure2. Bidirectional switches

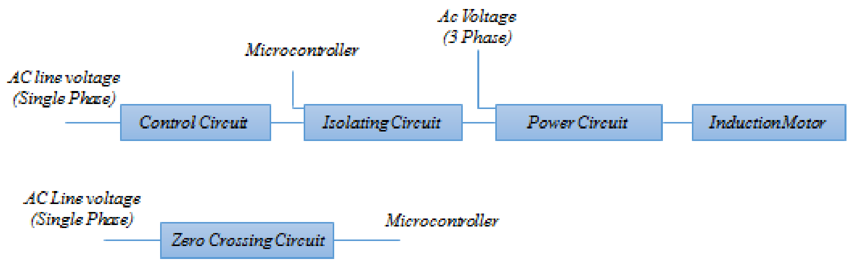


Figure 3 Block diagram of the structure of the system

The project is divide into sub-sequent parts, control circuit components, isolating circuit components, zero-crossing circuit components and power circuit components. Each of these component parts is related together to represent the entire system. Figure.3 shows the diagram of the structure of the system.

A. Control Circuit Components

This project included the output capacitor of 330 microfarads to help remove any distortion when it is supplying the analog circuits. The figure 4 shows the power the control circuit for one of the six switches. The components required are a transformer 110/18, rectifier bridge, capacitors 330uF, resistors 200K and regulator 7812.

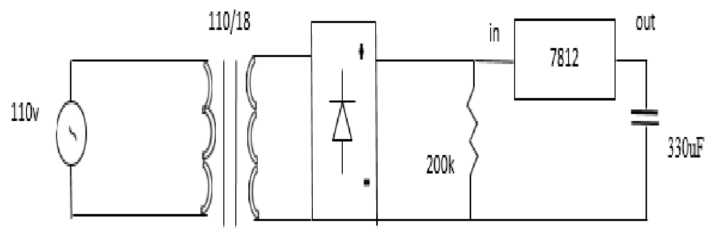


Figure4. Schematic diagram of the power supply module for one switch

B. *Isolating Circuit:*

The high voltage of main supply may damage the microcontroller if any misconnection happened between pins of the microcontroller port and the high voltage leads in the electronic circuit. It is recommended to take the outputs or give the inputs to the microcontroller within opto-coupler chip. Figure 5 shows the Isolating circuit for one of the six switches. The components required are transformer 110/18, rectifier bridge, capacitors 330uF, resistor 200K, resistor 10K, regulator 7812, opto coupler and ARM board.

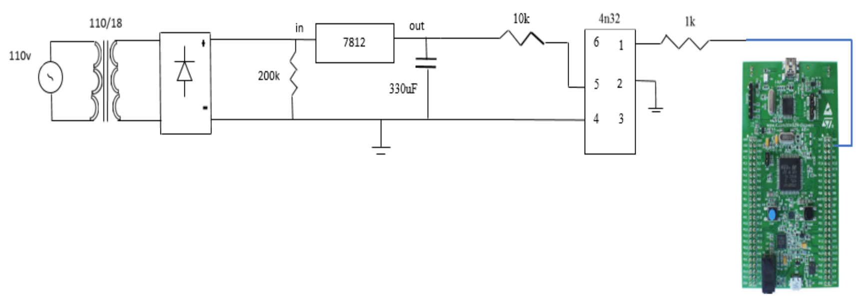


Figure5. Schematic diagram of the isolating circuit for one switch.

C. *Power Circuit:*

The power circuit consists of bidirectional switches. The point A and B are connected to three phase supply and stator windings correspondingly for series switches, and connected to same previous stator windings point and the ground of the machine respectively for parallel switches. Figure 6 shows the power circuit for one of the six switches. The components required are mosfet and high current diode.

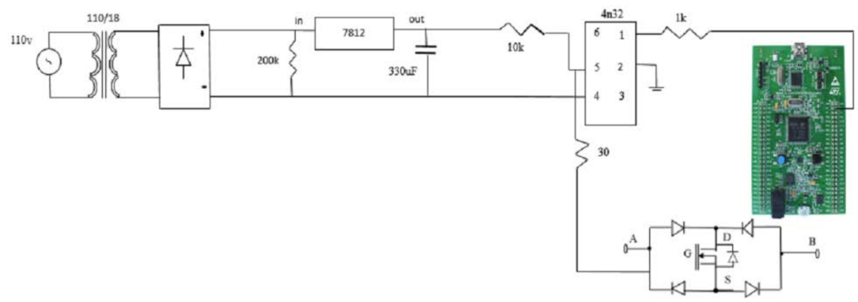


Figure6. Schematic diagram of power circuit for one switch.

D. Zero-crossing circuits:

It is necessary to synchronize the output pulse of the programming with the line voltage of the main supply of the circuit. To achieve the synchronization, a zero-crossing detector should be used to send a pulse to the program in the beginning of each cycle via the input pins of the Microcontroller. Also the program should read the Microcontroller at the end of each cycle to detect the beginning of the next cycle to maintain the synchronization all the time. Figure 7 shows the zero-crossing circuit for all switches. The components required are transformer 110/18, rectifier bridge, capacitors 330uF, resistor 200K, resistor 30K, resistor 1K, regulator

7812, Op amp 741 and ARM board.

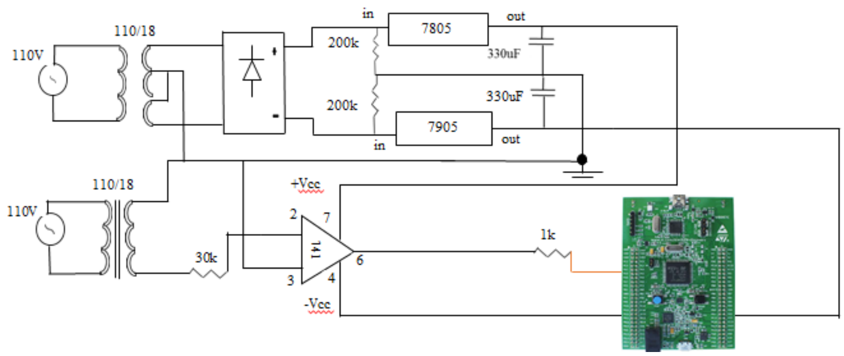


Figure.7 Schematic diagram of zero-crossing circuit

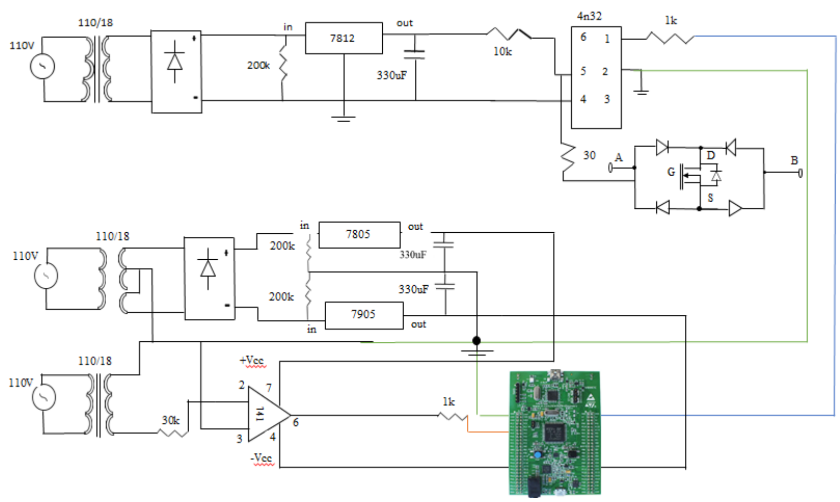


Figure.8 Schematic diagram of one switch

E. Microcontroller

In this project the microcontroller is to control the switches in order to control the speed of the three phase induction.

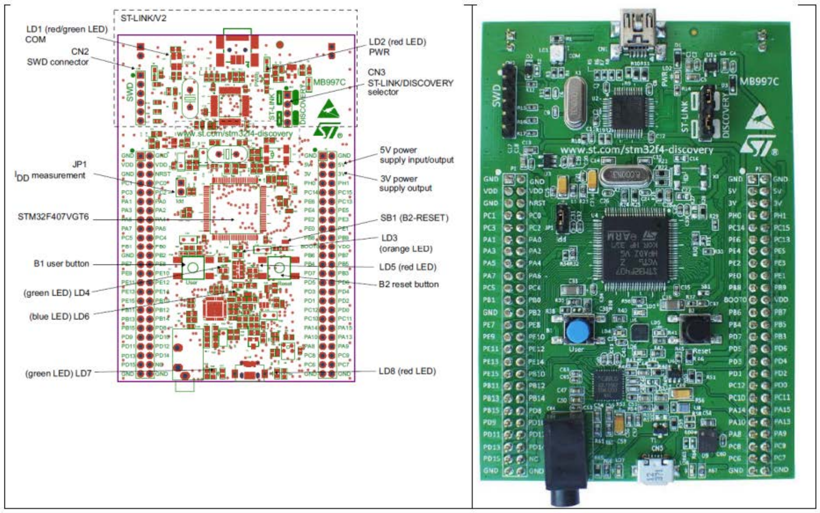


Figure9. The ARM board

F. Programming Language

For the software I used Keil Program, ……………. (not start it yet)

Table of Cost

To successfully implement the project, various materials necessary for the construction of the design needed to be obtained. Most of the items will be used for the control or the switching circuits and therefore most of the materials will be used as switches. For the project to be controlled and monitored, a computer will be used where the parallel ports will be interfaced with the control circuit. The total cost was $581.52 which is a bit high. Most of the funding will come from the engineering department of the university. However, the rest of the money was obtained from personal savings and assistance from family.

Item	Quantity	Approximate Price ($)/ unit	Total ($)
Power Diode	24	3.95	94.80
Transformers	8	11.12	88.96
Resistors	30	0.099	11
Voltage regulator	10	0.25-0.29	7.90
Power MOSFET	10	0.45	4.50
Opto coupler (4n32)	10	0.39	3.90
Op Amps	10	0.45	4.50
ARM board	1	15.96	15.96
3 Phase Induction Motor	1	350	350
Total			**$ 581.52**

IV. Result:

1- (LT spice)

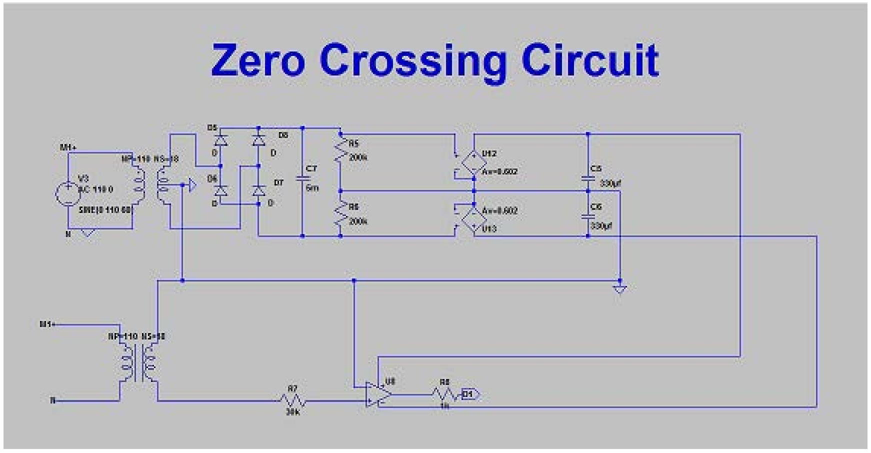


Figure.10 Zero Crossing Circuit (LT spice)

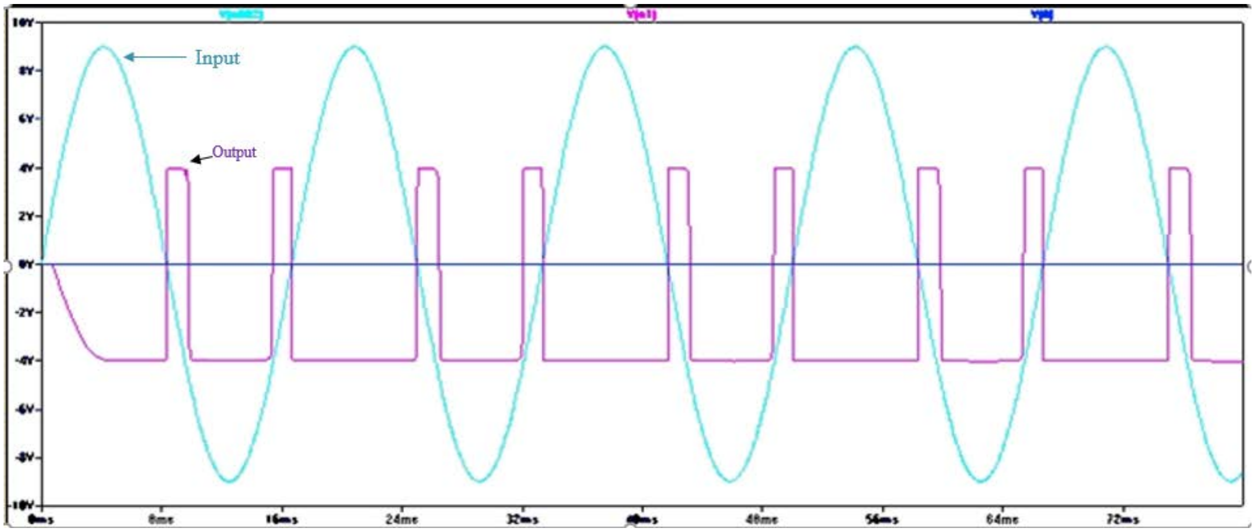


Figure.11 Zero Crossing Result

The blue line is input. The purple line is the output. From the figure11. We can see whenever the input it crosses the zero, the output get a pulse.

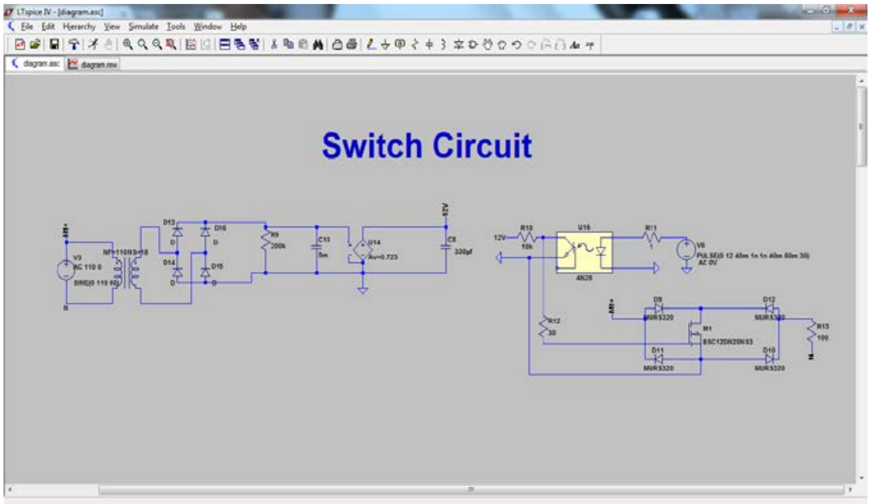


Figure12. Switching Circuit

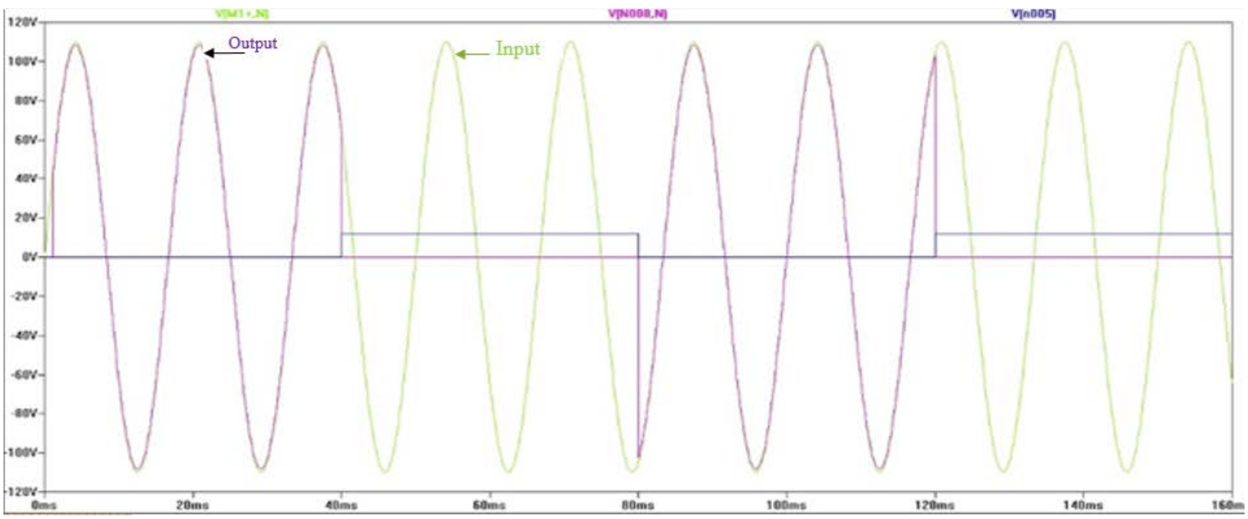


Figure13. Switching Circuit result

The purple line is output, the green is line input. We can see from figure13. At 0 input and output are on (the switch is open), at 1 input is on and the output is off (the switch is close).

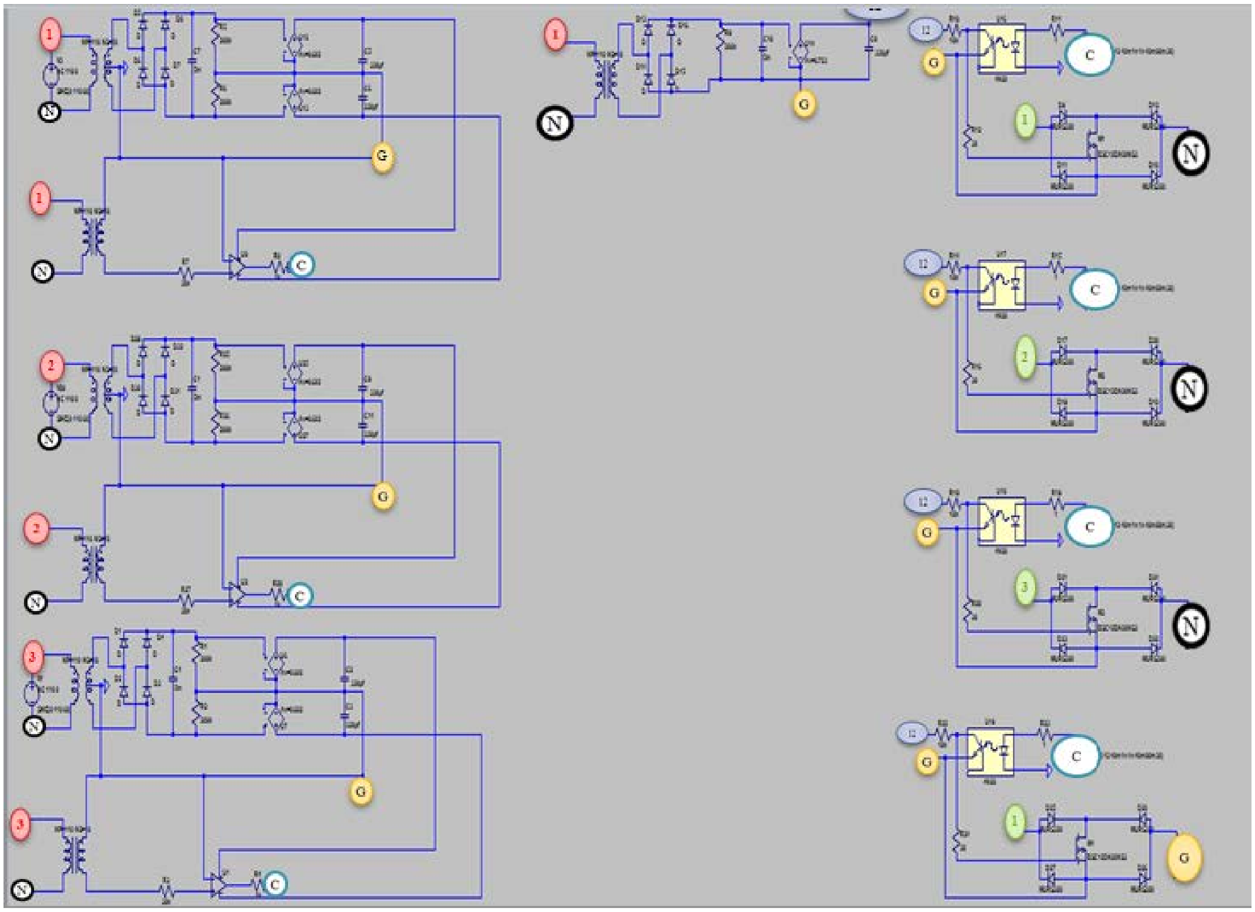


Figure14. Whole project LT spice

The red numbers are representing 3 AC supply and N are representing line natural. On the other hand, the green numbers are representing the three phase terminals, G are ground and C are wires to the microcontroller.

2- Hardware …… (still working on it)

Area	Codes & Standards
environmental	Feeding the system from renewable energy sources will explain how to use these sources to reduce the reduction of greenhouses gases generated from conventional power supplies.
political	Electrical energy became a vital issue in the modern countries. Direct starting of large scale induction motors directly on the electric utility may cause voltage dips or it may cause severe problems on the electric utility. Officials should address this points to avoid instability of power system

ethical	Direct starting of large scale three-phase induction motor may cause voltage dip or more trouble at the point of common coupling which may affects the neighbor's electrical supply or it may damage their devices. So, Soft starting reduce these problems which may affect neighbors.
health and safety	Using of soft starter circuits will increase the life time of three-phase induction motor and the water pump attached and it will prevent a voltage dip in the power system. All these benefits are translated to improve the health and safety of the customer and operator.

V. Conclusion*:*

Three-phase provide a simple and low cost option for speed control and starting of three-phase induction motor. Invention of modern fast switches as IGBT and MOSFET improves the performance of ac voltage regulators. This project uses a system that is specifically design to assess the different switching strategies to evaluate the performance parameters of a three-phase induction motor. In particular, this system uses six switches where three are in series with the project's supply terminals while the rest are connected in such a way that they offer a freewheeling path for the total stored energy in the windings of the motor. In particular, the switching strategies used include the Phase Angle Control (PAC), the Extinction Angle control (EAC) and the Symmetric Angle Control (SAC). When using the AC chopper, the goal is to control both the static and dynamic loads. In so doing, it changed the effective supply voltage applied hence the ability to control the speed of the motor. The output voltage of the specific strategies is going to be analyzed through the use a computer simulation using the LTspice program,

Reference

1. Bird, John. *Newnes Engineering Science Pocket Book*, 3rd ed. Newnes, 2011.
2. Serena. "What are the advantages and disadvantages of the induction motor." *Electrotechnik.* June, 2015, http://www.electrotechnik.net/2015/06/what-are-advantages-and-disadvantages.html. Accessed 4 December 2016.
3. El-Sharkawi. *Electric Energy*. New York, CRC Press, 2012, pp.398