Analysis of Induction Motor speed control fed from three phase inverter

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***Abstract* - The recent advancement in Semiconductor technology has led to development of Power Electronic systems. One of the significant applications of power electronic system is power converters which are very widely used in variable frequency drives and speed control of motors. Three phase voltage source inverters are proven to be very popular in variable speed AC drives for industrial applications. Due to the advent of power electronic technology, the speed control of AC drives has become very smooth and rapid. Because of latest developments in speed control of Induction motors, they are extensively used in majority of industries. The speed of the induction motor can be controlled by variable voltage or variable frequency or both. This paper presents speed control of induction motor fed from three phase inverter operated in three different modes. Simulations are carried out in MATLAB/ Simulink to demonstrate the performance of the induction motor under variable load conditions**

***keywords* - Induction motor, inverter, variable load.**

I. Introduction:

In recent past, DC motors were used in industries for variable speed applications due to easy controllability. Today, induction motors have become very popular for industrial applications due to low cost, high efficiency, robustness and less maintenance. In the past, for constant speed applications, induction motors were used as proper speed control techniques are not available. The development of power electronics has made it achievable to control the speed of induction motor by controlling the supply voltage, supply frequency or both. With the help of Torque-Speed characteristics, the performance of the induction motor can be evaluated.

In the last century, DC motors were in use for variable speed applications as the speed can be controlled by changing the armature and field currents. At the same time, it has got the advantage of operating in four quadrants of torque- speed plane. In these days, induction motors gained importance in industrial applications due to their low cost, high efficiency and robustness. At the same time, the development of semiconductor technology has made the speed control of these ac motor very smooth and rapid. The speed of the induction motor can be controlled by varying the supply voltage, supply frequency or both. It is possible to vary the voltage as well as frequency using voltage source inverter circuit.

II. THREE PHASE INVERTER

Three phase inverters are widely used in variable speed drives. They fabricate variable voltage by applying proper control methods. The output of the inverter can be varied by varying the width of the pulse. A three phase bridge inverter consists of six switches which are operated in a proper sequence. A balanced output voltage can be developed by operating the inverter in three different modes viz. 120^0 , 150^0 and 180^0 .

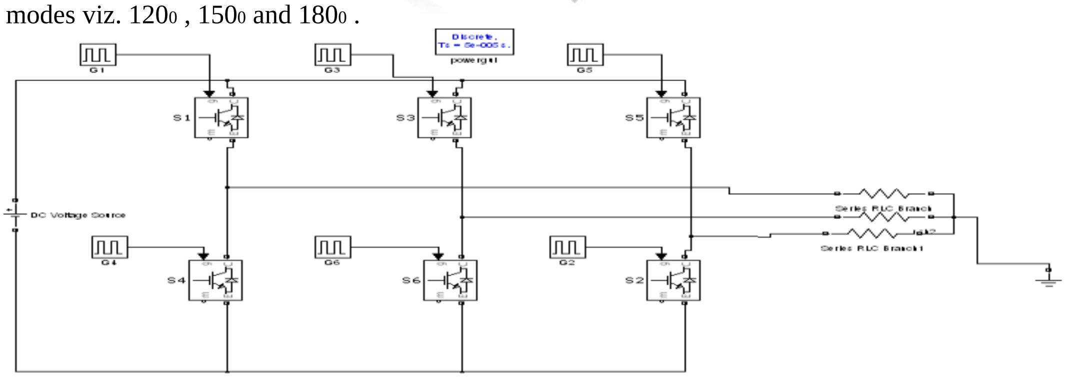

Fig. 1 Three phase inverter circuit

a) 180^0 mode of operation:

In this mode, each switch conducts for 180^0 of a cycle. The switch pairs in each leg are turned ON with an interval of 180^0. It means that S_1 conducts for 180^0 and S_4 for next 180^0 of a cycle. The switches in the upper group conduct at an interval of 120^0 and same case with lower group. If S_1 is triggered at $\omega t = 0^0$, then S_3 must be fired at 120^0 and S_5 at 240^0. The switching sequence is 1,2,3,4,5,6 and interval between the consecutive switches is 60^0. At any given instant of time, three switches will be in ON state – one from upper group and two from lower group or two from the upper group and one from the lower group.

Table –I 180^0 mode of operation

Interval	Duration	Conducting Switches							
1	180^0	S1	S2	S3					
2	180^0		S2	S3	S4				
3	180^0			S3	S4	S5			
4	180^0				S4	S5	S6		
5	180^0					S5	S6	S1	
6	180^0						S6	S1	S2

b) 150^0 mode of operation:

In this mode, each switch conducts for 150^0 of a cycle. As in case of 180^0 , this mode also requires twelve steps, each of 30^0 duration for completing one cycle of the output voltage. Here, S_1 from leg1 conducts for 150^0 and for the next 30^0 neither S_1 nor S_4 conducts. Now, S_4 is turned ON at 180^0 and it conducts for 150^0. From the second leg, S_3 is turned ON at $\omega t = 120^0$ and conducts for 150^0 . Then for the next 30^0 interval neither S_3 nor S_6 conducts. Similar switching process takes place for the third leg switches also. During each step, either two switches or three switches conduct i.e two and three switches are in conduction alternately. Here also, the switching sequence is 1,2,3,4,5,6 and interval between the consecutive switches is 60^0.

Table –II 150^0 mode of operation

Interval	Duration	Conducting Switches							
1	150^0	S1	S2	S3					
2	150^0		S2	S3					
3	150^0		S2	S3	S4				
4	150^0			S3	S4				
5	150^0			S3	S4	S5			
6	150^0				S4	S5			
7	150^0				S4	S5	S6		
8	150^0					S5	S6		
9	150^0					S5	S6	S1	
10	150^0						S6	S1	
11	150^0						S6	S1	S2
12	150^0							S1	S2

c) 120^0 mode of operation:

In this mode, each switch conducts for 120^0 of a cycle. As in case of 180^0 , this mode also requires six steps, each of 60^0 duration for completing the cycle of the output voltage. Here, S_1 conducts for 120^0 and for the next 60^0 neither S_1 nor S_4 conducts. Now, S_4 is turned ON at 180^0 and it conducts for 120^0. In the second leg, S_3 is turned ON at $\omega t = 120^0$ and conducts for 120^0 . Then, 60^0 interval elapsed during which neither S_3 nor S_6 conducts. Similar switching process takes place with the third leg switches also. During each step only two switches conduct , one from the upper group and one from the lower group. Here also, the switching sequence is 1,2,3,4,5,6 and interval between the consecutive switches is 60^0.

Table –III 120^0 mode of operation

Interval	Duration	Conducting Switches						
1	120^0	S1	S2					
2	120^0		S2	S3				
3	120^0			S3	S4			
4	120^0				S4	S5		
5	120^0					S5	S6	
6	120^0						S6	S1

III. Simulation Results:

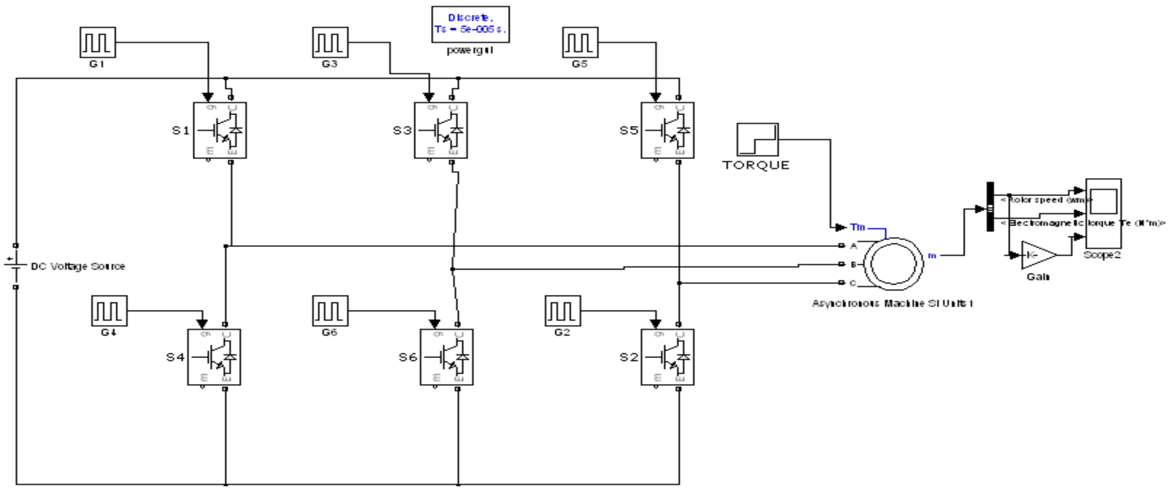

Fig.2. Simulation diagram of Inverter fed induction motor

a) 120 deg mode of operation of inverter:

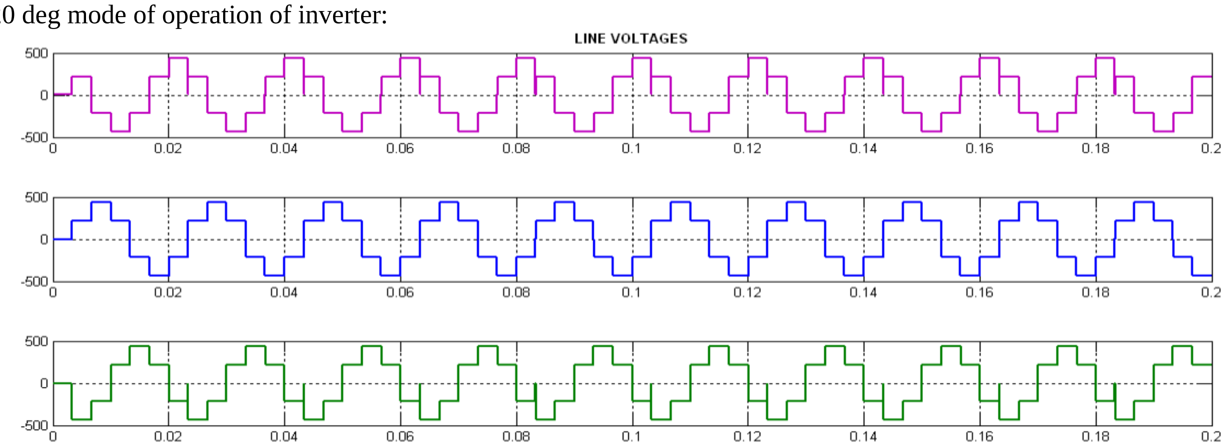

Fig.3 Line voltages of inverter with 120 deg mode

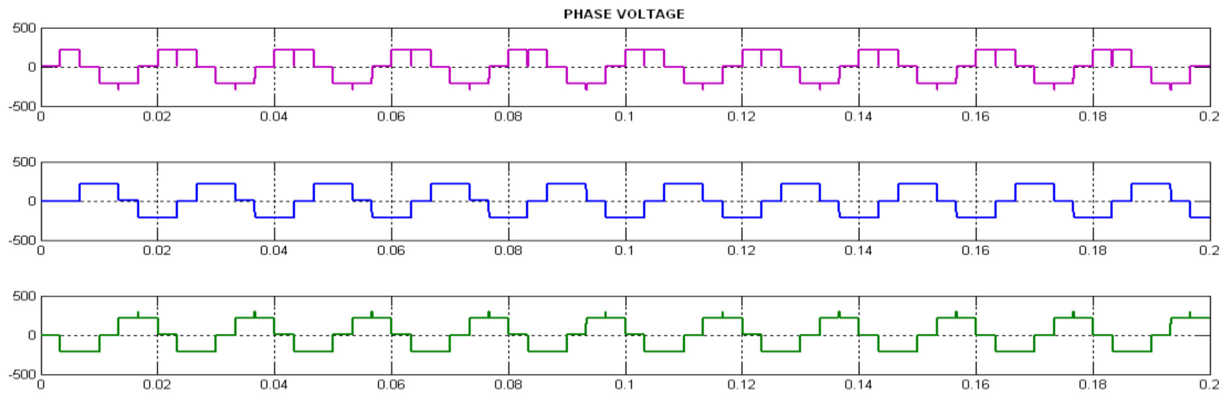

Fig.4 Phase voltages of inverter with 120 mode

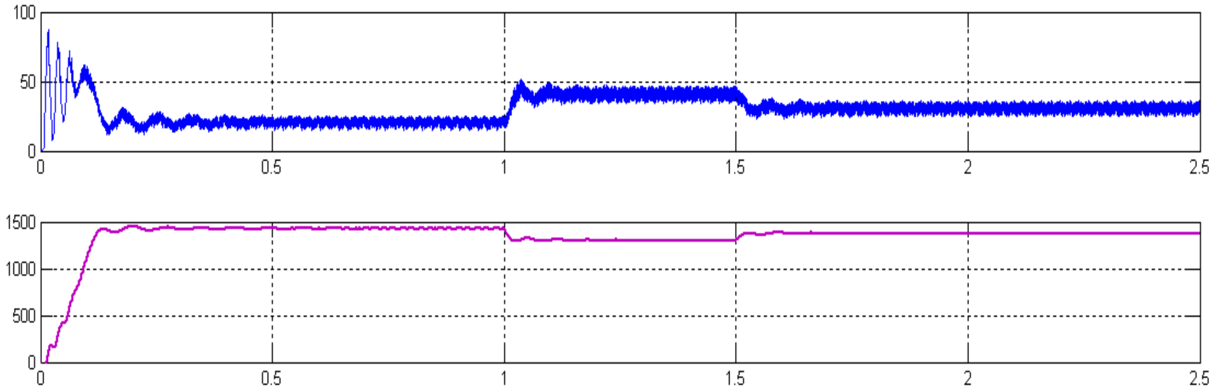

Fig.5. Torque and speed characteristics of induction motor

A variable load is applied to the induction motor to study its performance when fed from three phase inverter operated in three different modes. From Fig.5 it is clear that, the torque is undergoing transients for a longer time before settling to the final steady value. Similar case with speed also. At the same time, the torque is appearing to be a wide band about the final value.

b) 150 deg mode of operation of inverter

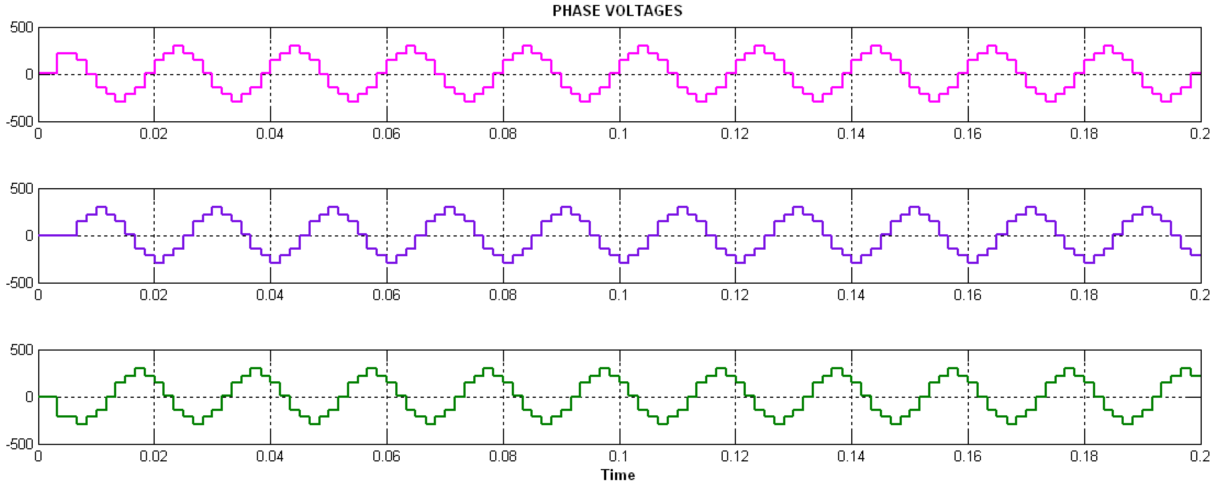

Fig.6 Phase voltages of inverter with 150 mode

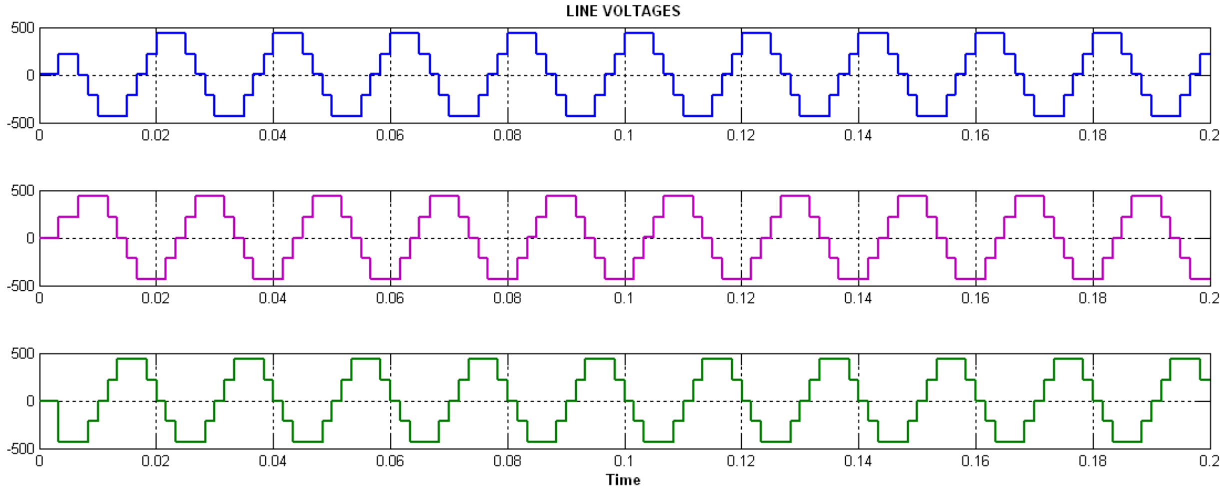

Fig.7 Line voltages of inverter with 150 mode

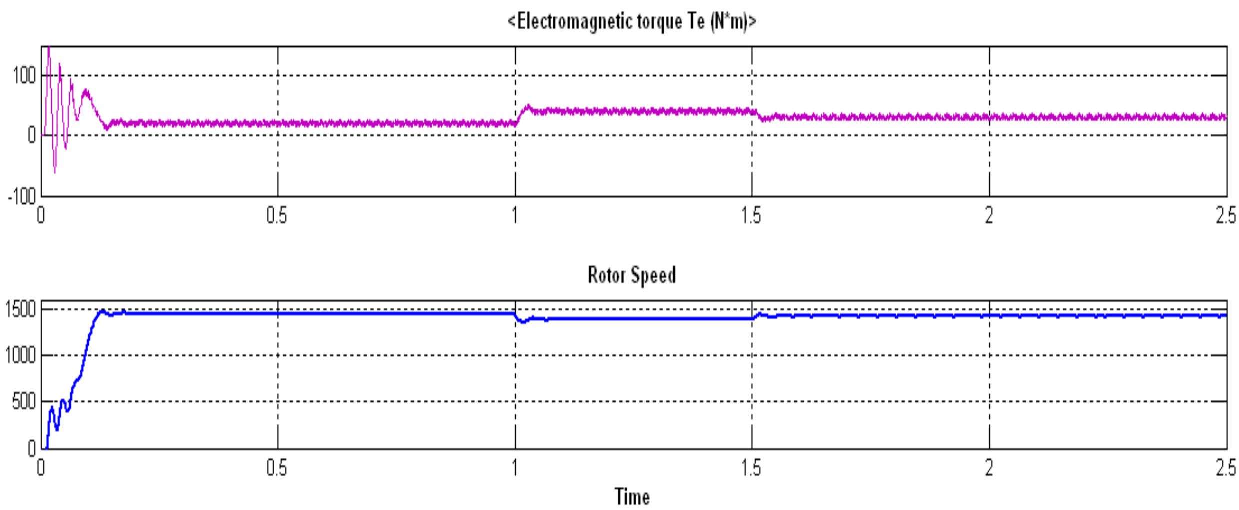

Fig.8. Torque and speed characteristics of induction motor

b) 180 deg mode of operation of inverter

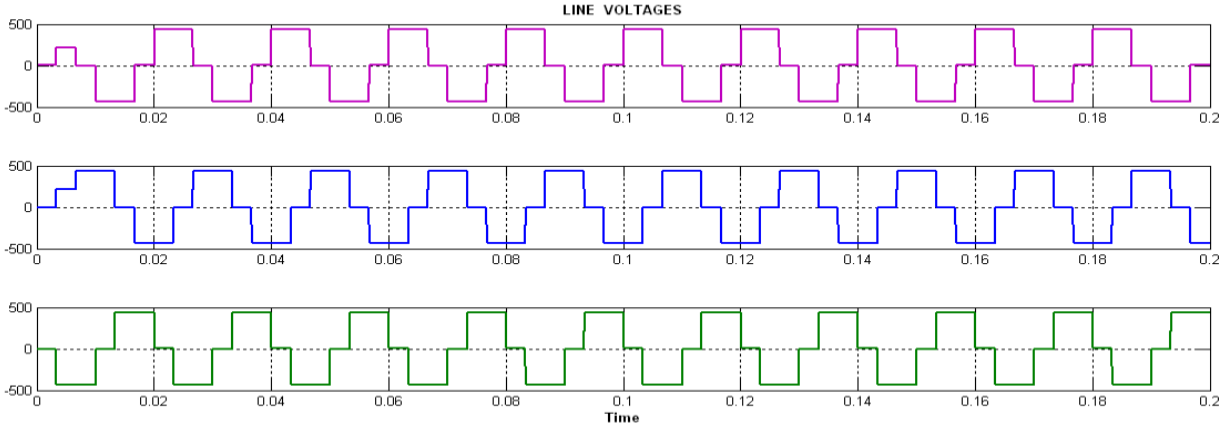

Fig.9 Line voltages of 180 deg mode of operation

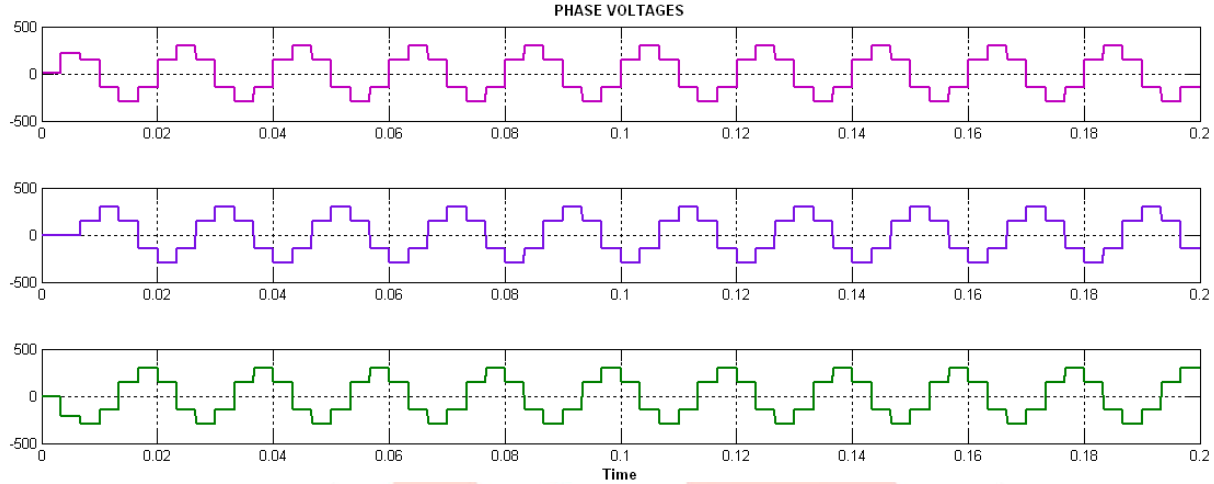

Fig.10 Phase voltages of 180 deg mode of operation

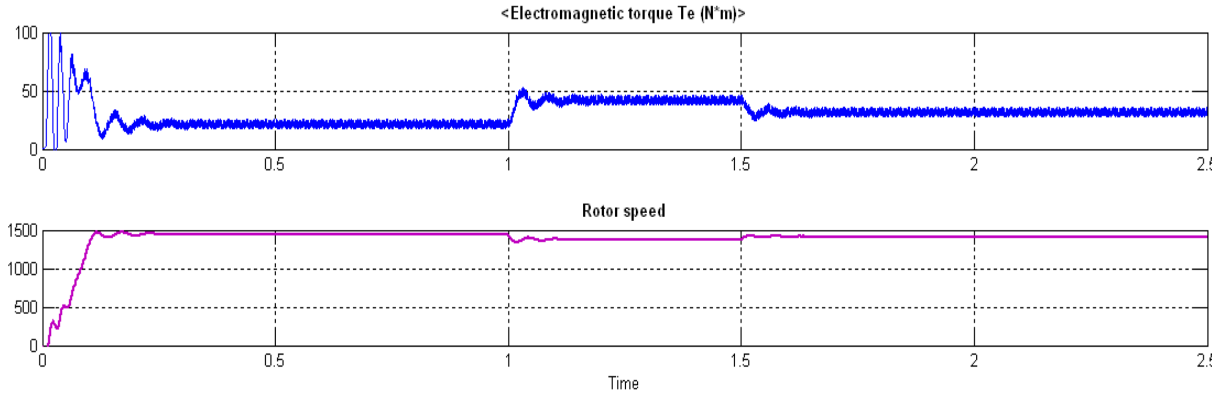

Fig.11. Torque and speed characteristics of induction motor

From Fig.5, Fig.8 and Fig. 11 , it is clear that the speed has settled to a final value with less transients at every step of change in load in case of 150 deg mode whereas the same is settling to final value with transients of greater time for 120 deg mode and 180 deg mode. At the same time, the torque is also settling to final value with less transients in case of 150 deg mode compared to that of 120 deg and 180 deg mode. Also, it is observed that that the torque is having a thinner band in case of 150 deg mode compared to 120 deg and 180 deg mode of operation.

IV. CONCLUSION

Three phase induction motor fed from three phase inverter operated in three different modes is simulated. In order to validate the performance of the Induction Motor, simulation is carried out by operating the inverter in 120 deg , 150 deg and 180 deg modes. From the simulation results it is very clear that the the speed as well as torque are settling to final value with less transients in case of 150 deg mode of operation compared to 120deg and 180 deg modes of operation. It is concluded that the operation of Induction Motor is superior when fed from 150 deg mode operated three phase inverter.

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