Direct Torque Control Design for Three Phase Induction Motor

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***Abstract* - Three phase induction motors are most widely used electric motor. In addition to that eighty percentage of mechanical power used by industries are provided by three phase induction motors and also in many industrial applications the induction motor are used because of the merits like easy maintenance, low cost, robustness and better performance. In this paper the direct torque control model is designed and tested through MATLAB / SIMULINK software for torque and speed control of induction motor. In addition to these parameters like d and q stator current, d and q axis flux, torque and speed are obtained graphically.**

***Keywords* - DTC, Speed Control, Induction motor.**

I. INTRODUCTION

The induction motor or asynchronous is the most widely used electrical drive. [1] Has explained the complete analysis of electrical machinery drive system. Actually because independent control of torque and flux separately excited dc drives are simpler in control. Due to ruggedness, efficiency and simplicity the induction motors have been used in several applications for over a century. [2-3] has presented the analysis and simulation model development of induction motor in MATLAB / SIMULINK software. In AC drives control the direct torque control scheme is considered as one of the most advanced technology in the modern world. The direct torque control scheme is a simple technique compare to other techniques. In this technique by selecting optimum inverter switching modes the motor torque and flux are controlled independent and also direct. The primary input of the motor is stator voltage and stator current. From this the stator flux and electromagnetic torques are calculated. The torque errors and flux errors are restricted within the hysteresis band. The two important merits of this direct torque control technique is improved in steady state efficiency and quick torque response in transient operation.

II. BLOCK DIAGRAM OF PROPOSED SYSTEM

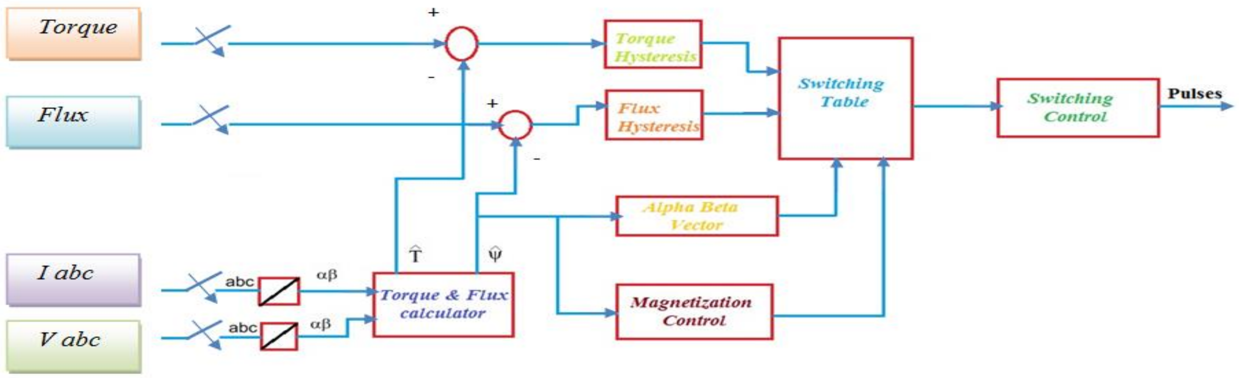

Figure.1. Block diagram of direct torque control

Alpha and beta are the two flux components of the motor. The flux components and the electromagnetic torque are estimated under the block torque flux calculator. So this estimation is done on the basis of motor equations. Actually there are six sectors spaced by sixty degree in alpha beta plane. The flux vector lies in the sector of alpha beta plane. Therefore in order to discover alpha beta the vector block is used. The flux and torque control is done by hysteresis control block. In particular the torque control is done by using 3-level hysteresis comparator and the flux control is done by 2-level hysteresis comparator. Once the output is generated by the torque and flux of the hysteresis comparator. Then from the look table which is present inside the switching table block will select the specific voltage vector. At the same time the initial flux for the machine is also produced. In order to limit the inverter commutation frequency the switching control block is used. [3-8] has explained in detail about direct torque control approach in three phase induction drive system.

III. DIRECT TORQUE CONTROL AND VOLTAGE SOURCE INVERTER PRINCIPLE

The torque HB value is nothing but a total value of bandwidth distributed symmetrically around the torque set point. In the below figure.2 torque set point and torque hysteresis bandwidth are shown clearly. The torque set point and torque hysteresis band are denoted as Te and dTe respectively.

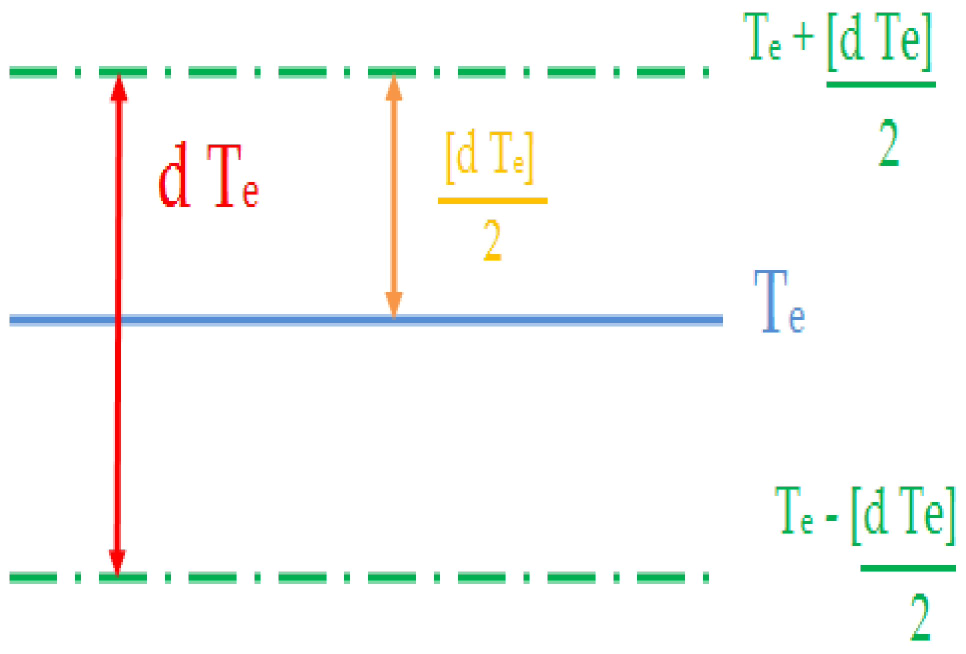

Figure.2.HB-Torque

The flux HB value is nothing but a total value of bandwidth distributed symmetrically around the flux set point. In the below figure.2 flux set point and flux hysteresis bandwidth are shown clearly. The flux set point and flux hysteresis band are denoted as ψ and $d\psi$ respectively.

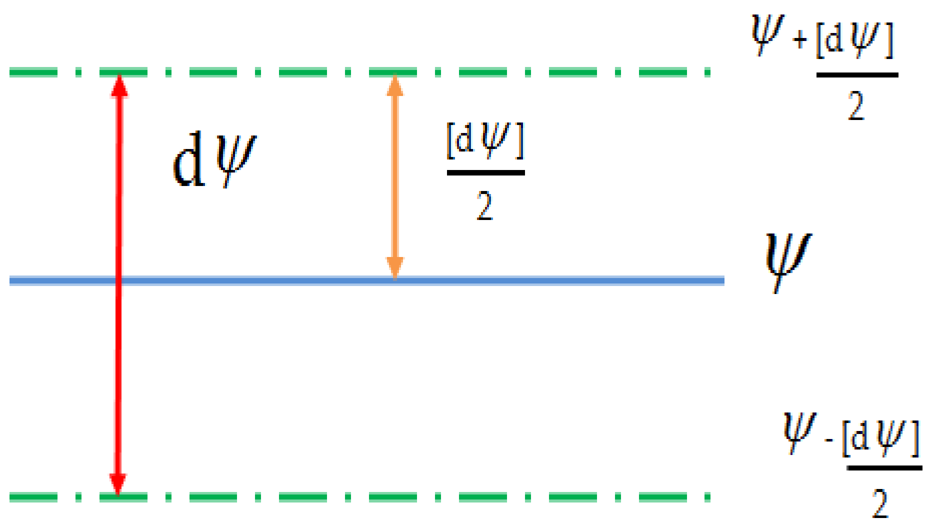

Figure.3.HB-Flux

The figure.4 shows the three phase voltage source inverter. The inverter consists of three leg and six switches. In every switch of the inverter two back to back connected semiconductors will be used. But in that two switches one will be a controllable device and the other will be a diode for protection. The voltage waveforms for all the three phases are shown in figure.5. At the same tine from figure.2 it is observed that the state of one inverter leg changes after an interval of sixty degree and then it state remains constant for sixty degree interval. Therefore the leg voltage will have six distinct and discrete values in one cycle of three sixty degree.

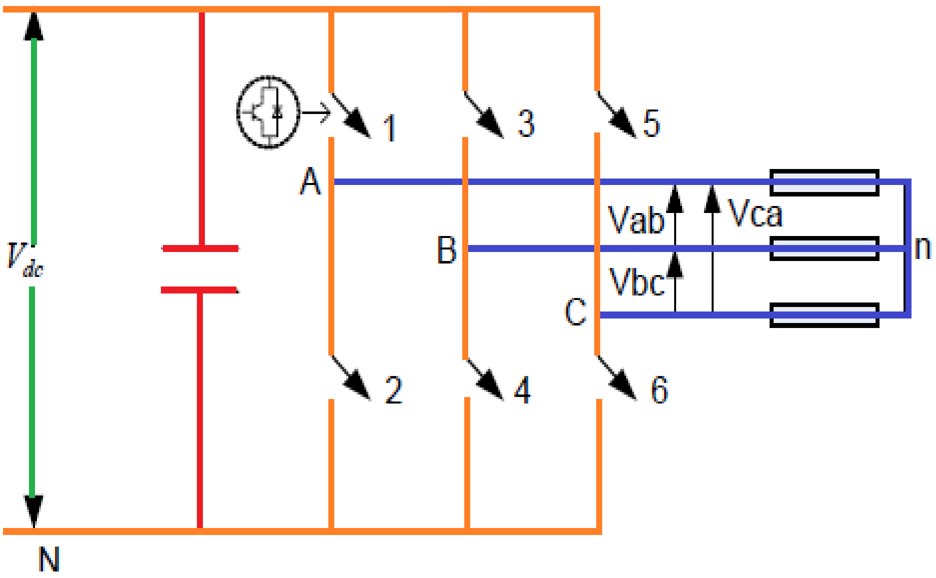

Figure.4. Circuit diagram of three phase voltage source inverter

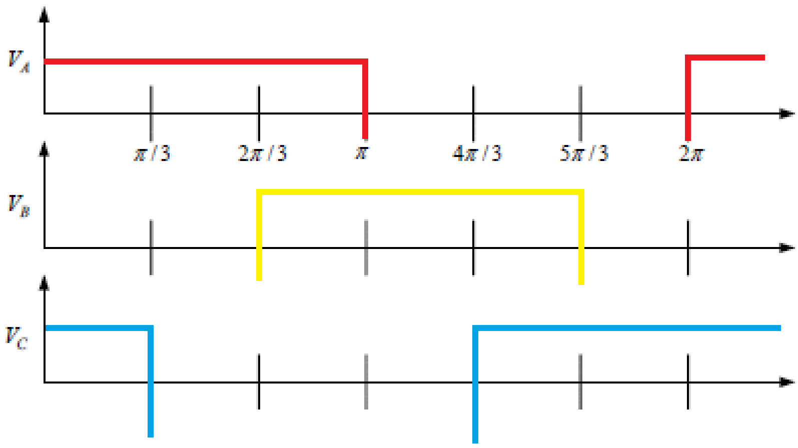

Figure.5. Voltage source inverter waveform for 180 degree mode of conduction

IV. MATHEMATICAL MODEL OF DIRECT TORQUE CONTROL

Once the flux of the stator and rotor is interacted the electromagnetic torque is produced.

$$T_e = \frac{3}{2}\left[\frac{P}{2}\right]\frac{L_m}{L_s{}'L_r}\overline{\psi_s} * \overline{\psi_r} \rightarrow Equation.1$$

$$T_e = \frac{3}{2}\left[\frac{P}{2}\right]\frac{L_m}{L_s{}'L_r}\psi_s\psi_r \sin\gamma \rightarrow Equation.2$$

The stator flux assessment is done on the basis of stator voltage model and current model. The equation 3, 4 and 5 represents stator voltage equations. In case of current model equation 6 and 7 are used.

$$\psi_{ds}{}^s = \int\left[V_{ds}{}^s - i_{ds}{}^s R_s\right]dt \rightarrow Equation.3$$

$$\psi_{qs}{}^s = \int\left[V_{qs}{}^s - i_{qs}{}^s R_s\right]dt \rightarrow Equation.4$$

$$\psi_s = \sqrt{\psi^s{}_{ds}{}^2 + \psi^s{}_{qs}{}^2} \rightarrow Equation.5$$

$$\frac{d}{dt}\overline{\psi_r} = \left[\frac{\left[\left(L_m i_s - \psi_r\right)\right]}{T_r} - \omega_r\psi_r\right] \rightarrow Equation.6$$

$$\overline{\psi_s} = \left[\frac{L_m}{L_r}\psi_r + \sigma L_s i_s\right] \rightarrow Equation.7$$

In hysteresis torque controller it has three cases as follows:

Case (I) $|dT_e| = 1$

If $|T_e| < |T_{eref}| - |\Delta T_e| \rightarrow Equation.8$

Case (II) $|dT_e| = -1$

If $|T_e| > |T_{eref}| - |\Delta T_e| \rightarrow Equation.9$

Case (III) $|dT_e| = 0$

If $|T_{eref}| - |\Delta T_e| \le |T_{eref}| + |\Delta T_e| \rightarrow Equation.10$

$\Delta T_e = T_{eref} - T_e \rightarrow Equation.11$

In hysteresis flux controller it has two cases as follows:

Case (I) $|d\psi_s| = 1$

If $|\psi_s| \le |\psi_{sref}| - |\Delta \psi_s| \rightarrow Equation.12$

Case (II) $|d\psi_s| = 0$

If $|\psi_s| \ge |\psi_{sref}| + |\Delta \psi_s| \rightarrow Equation.13$

V. SIMULATION MODEL OF DIRECT TORQUE CONTROL OF THREE PHASE INDUCTION MOTOR

The simulation results are given for the induction motor for the following specification:
Number of poles [P] = 4, Frequency [F] = 50 Hz, Number of phases = 3, Stator resistance [Rs] = 4 ohms, Rotor resistance [Rr] = 8 ohms, Stator inductance [Ls] = 350 mH, Mutual inductance [Lm] = 290 mH, Moment of inertia [J] = 0.00288 Kg-m/sec.

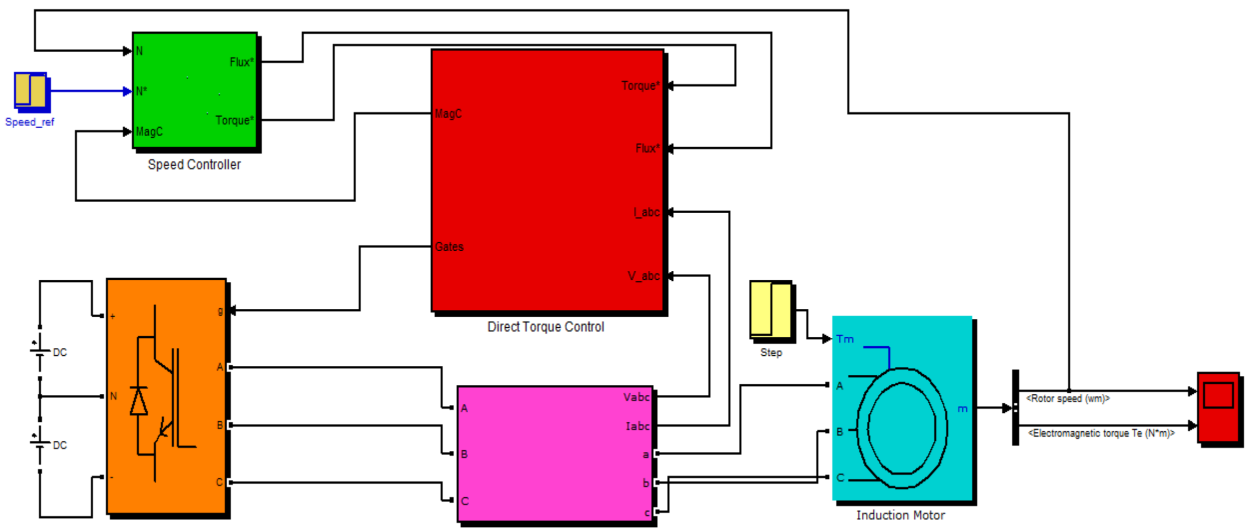

Figure.6.MATLAB simulink model of direct torque control of three phase induction motor

The figure.6 shows the complete MATLAB / SIMULINK model of the direct torque control scheme for three phase induction motor. The step by step subsystem model of the direct torque control method is shown figure.6, figure.7, figure.8, figure.9 and figure.10. These subsystem models are designed on the basis of the mathematical equation of direct torque method is discussed in chapter 4.

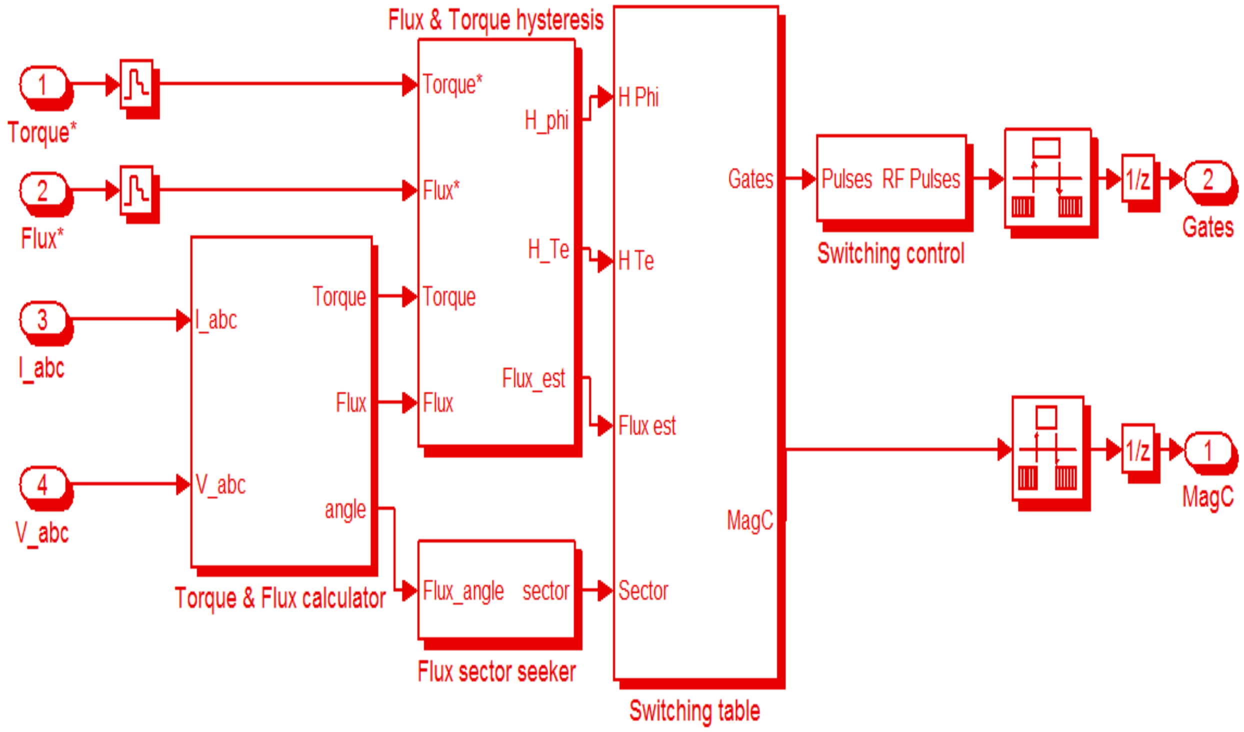

Figure.7.MATLAB simulink subsystem model for direct torque control

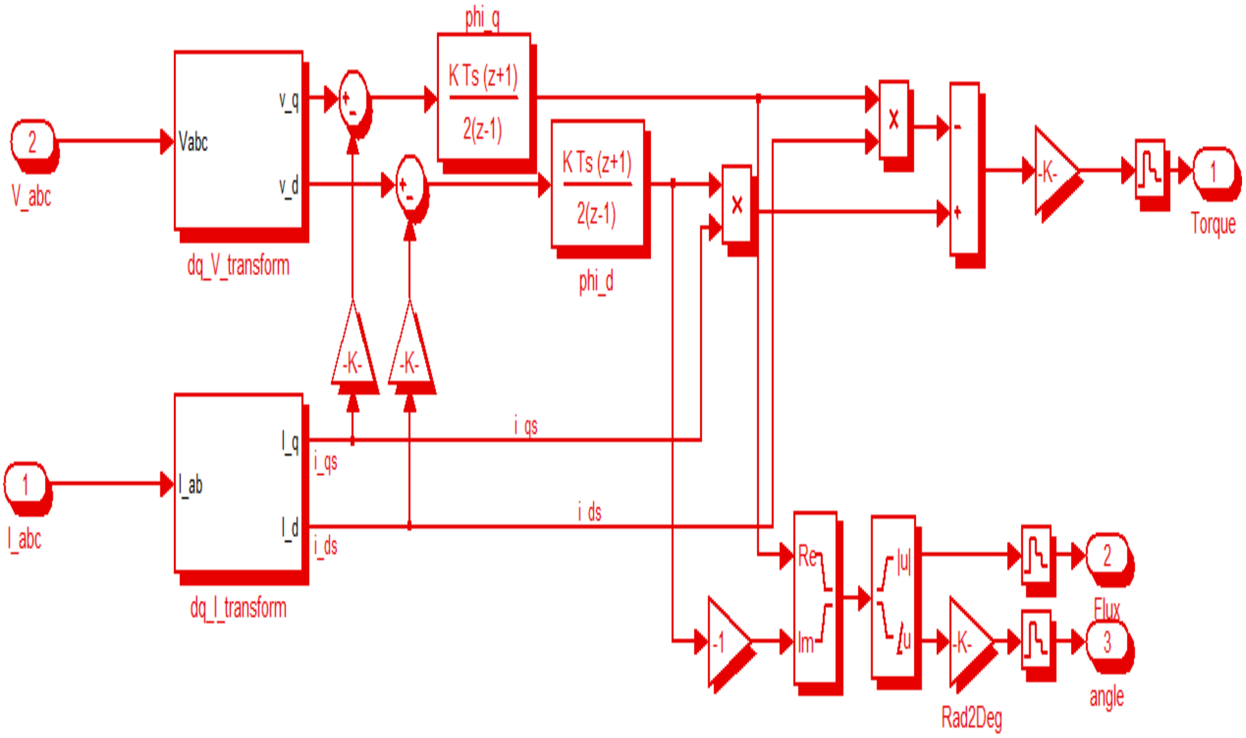

Figure.8.MATLAB simulink subsystem model for calculating torque & flux

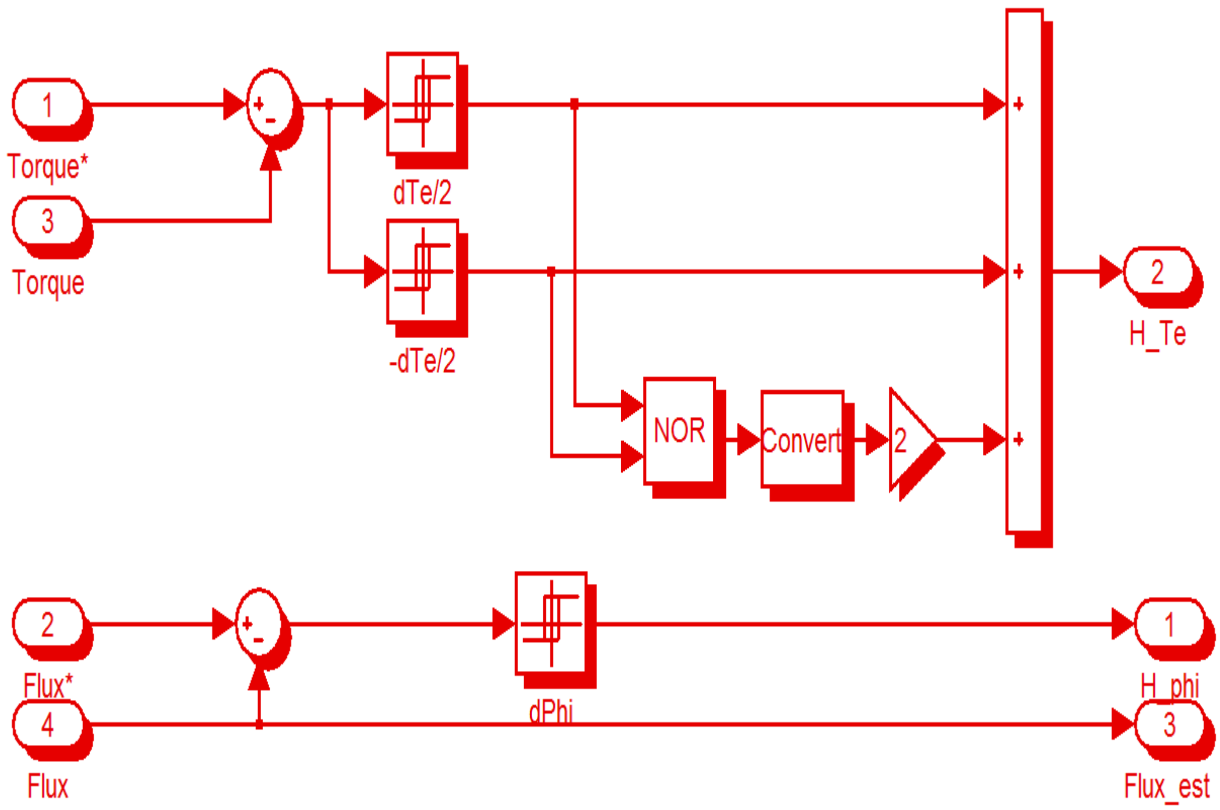

Figure.9.MATLAB simulink subsystem model for calculating hysteresis torque & flux

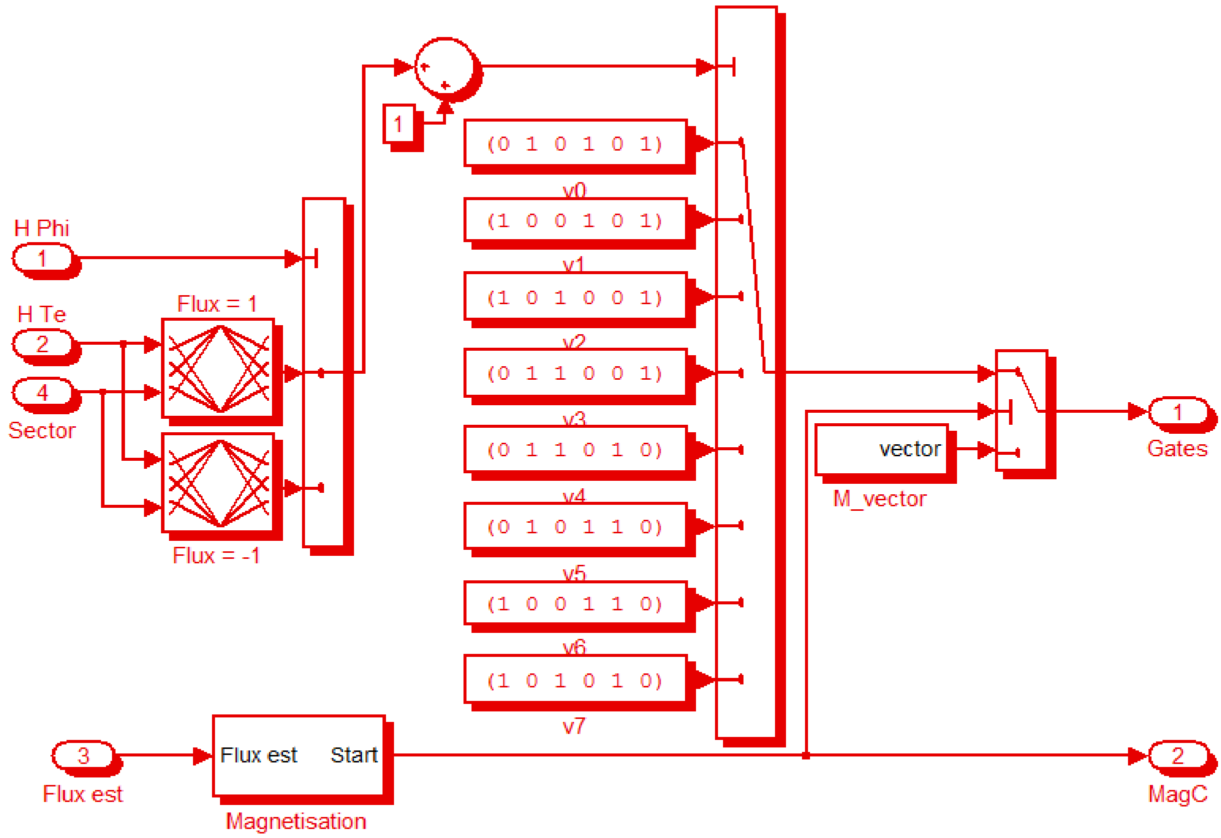

Figure.10.MATLAB simulink subsystem model for switching table

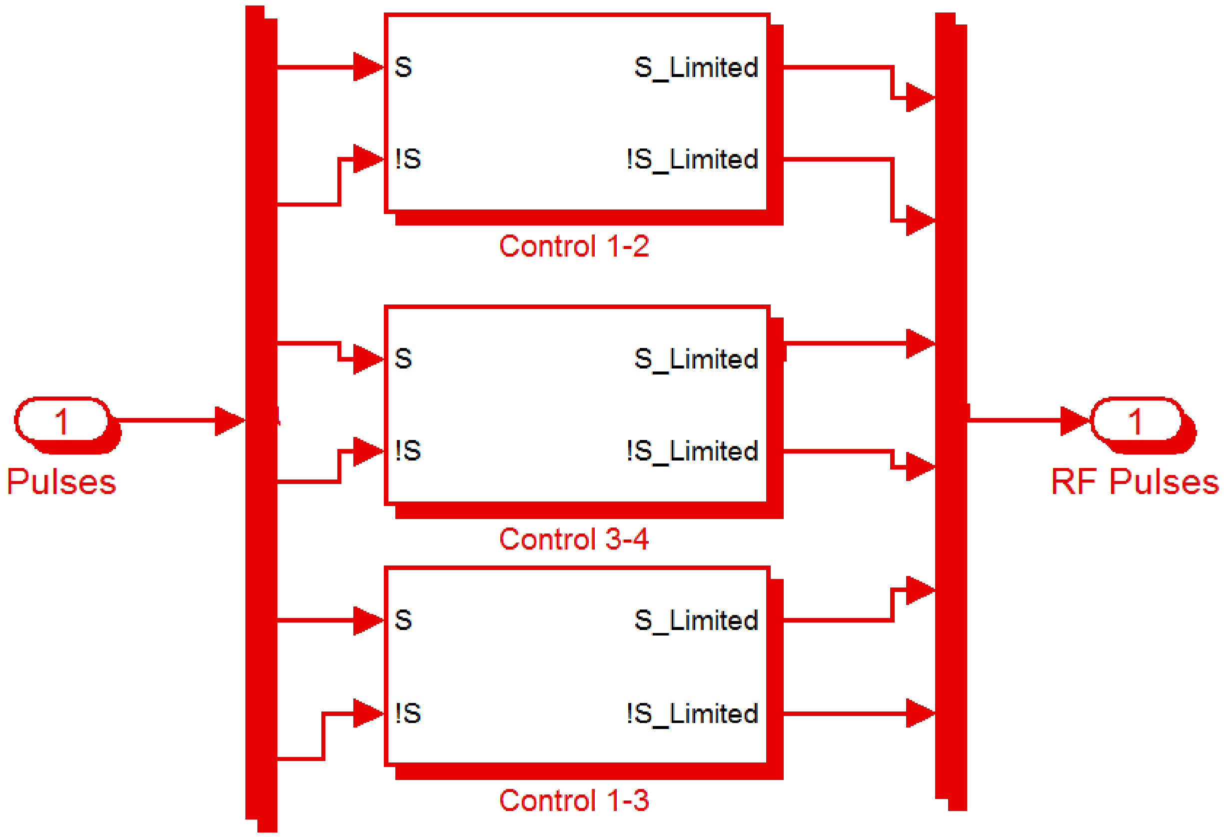

Figure.11.MATLAB simulink subsystem model for switching control

VI. SIMULATION RESULTS

[A] d-Axis Stator Flux

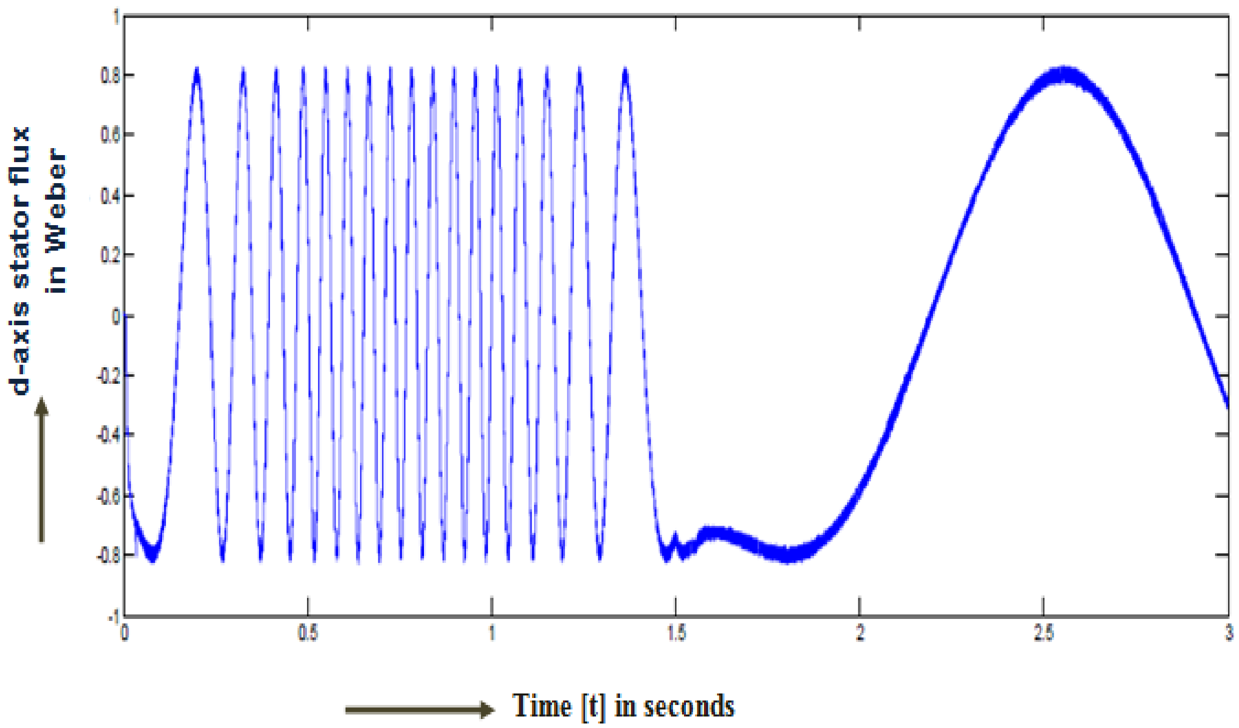

Figure.12.d-Axis stator flux in Weber

[B] q-Axis Stator Flux

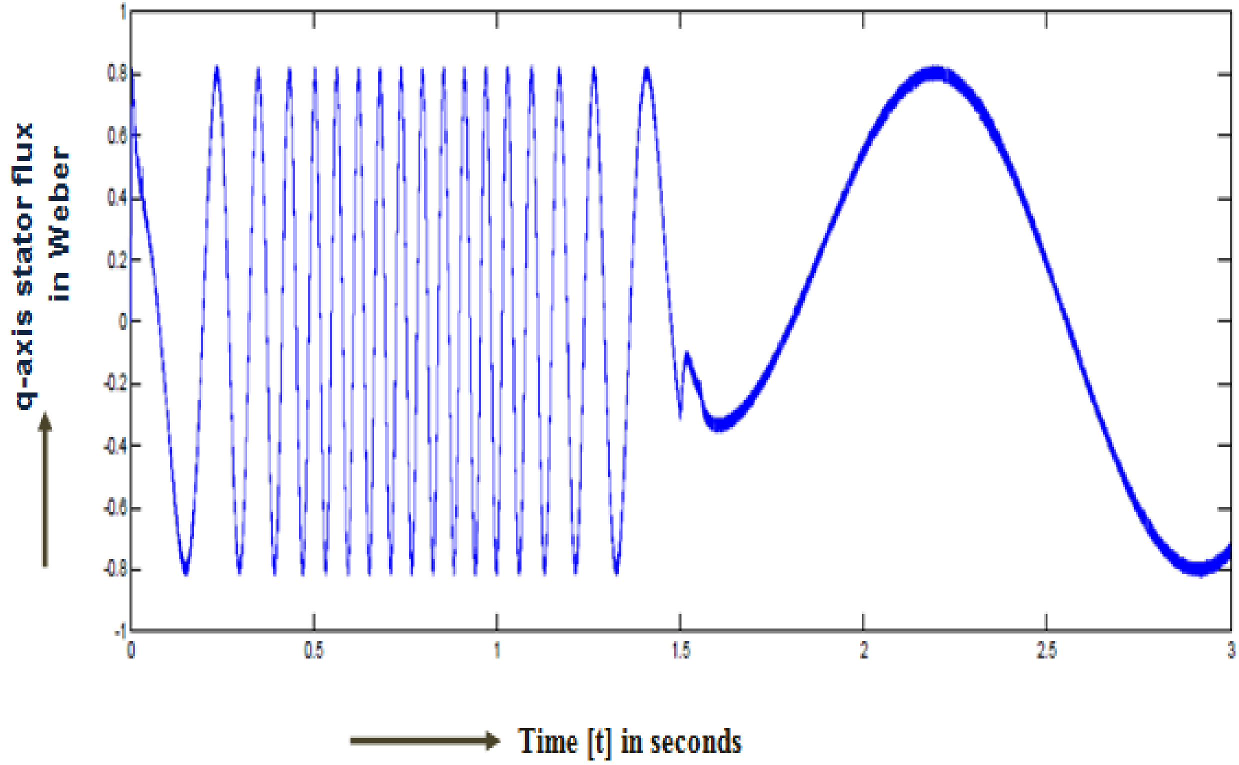

Figure.13.q-Axis stator flux in Weber

[C] d-Axis Stator Current

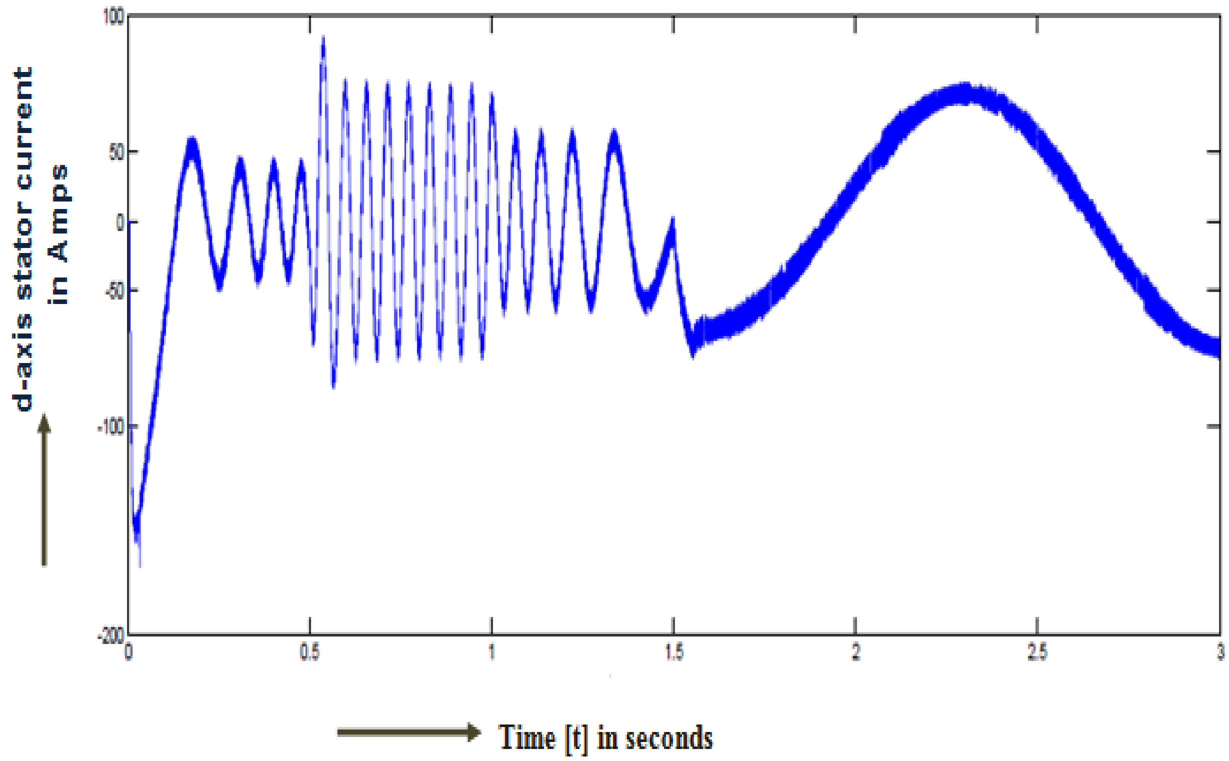

Figure.14.d-Axis stator current in Weber

[D] q-Axis Stator Current

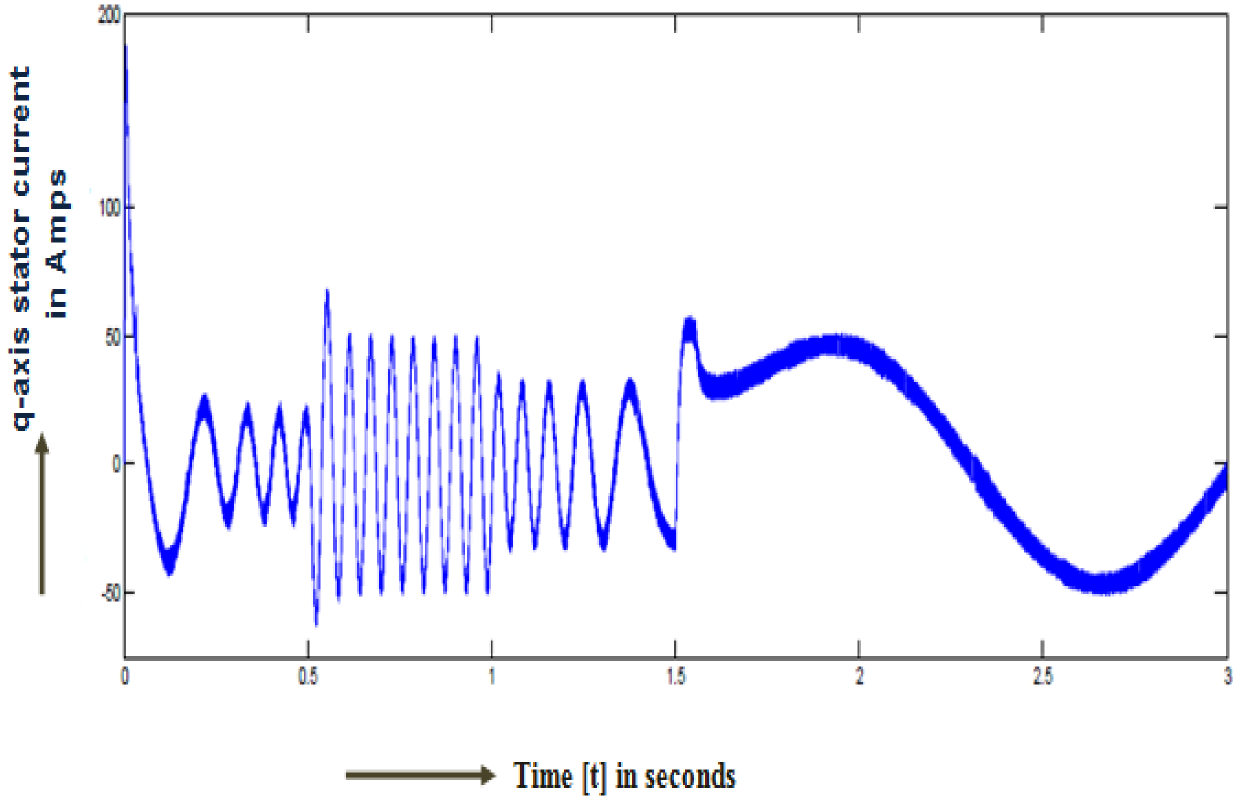

Figure.15.q-Axis stator current in Weber

[E] Torque

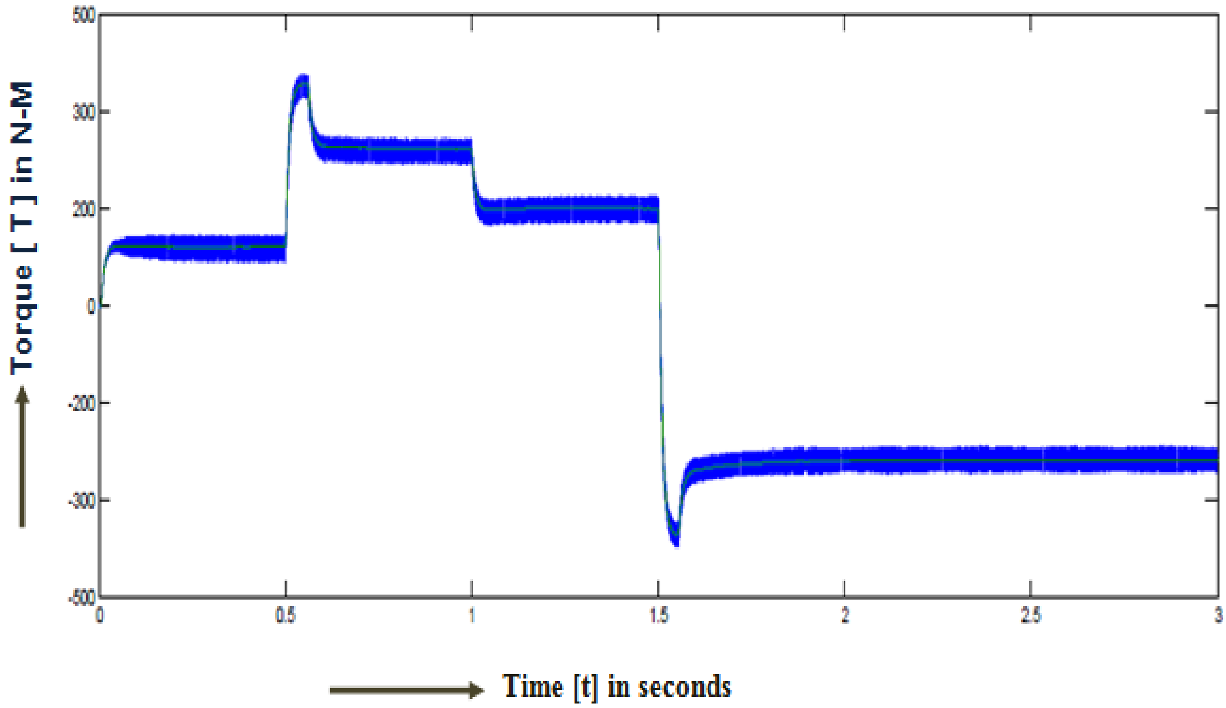

Figure.16.Torque [T] in N-M

[F] Speed

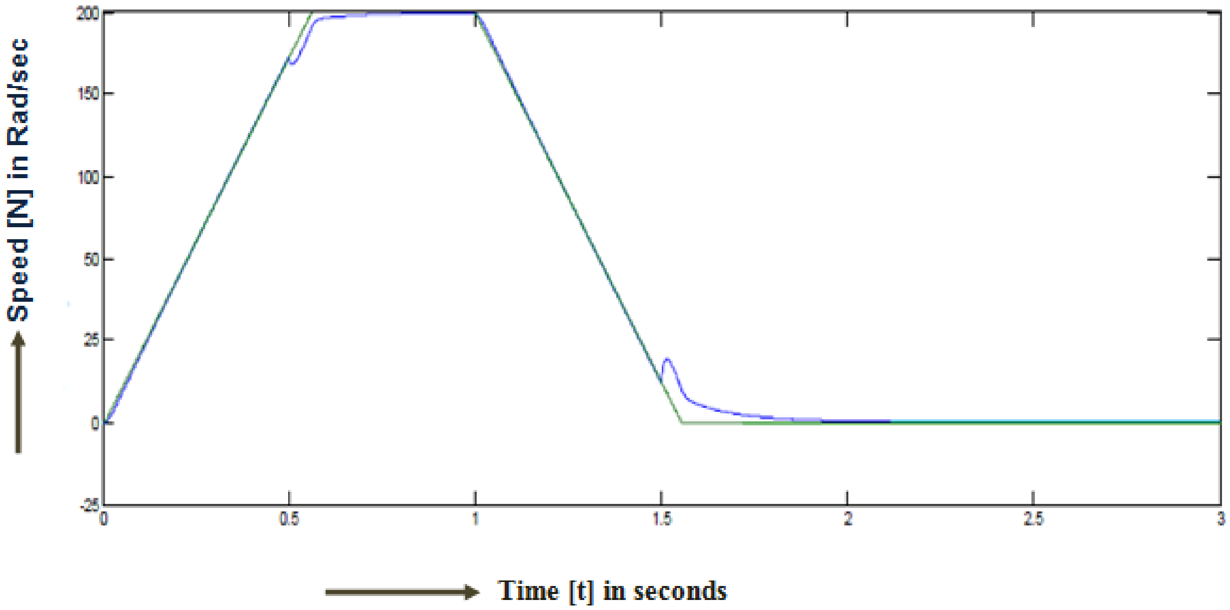

Figure.17.Speed [N] in Rad/sec

VII.CONCLUSION

In this research paper direct torque control for induction motor model is designed through MATLAB software and also tested successfully by evaluating the parameters like d and q stator current, d and q axis flux, torque and speed. From the figure.16 and figure.17 we infer that developed direct torque control model is achieved high dynamic performance in speed response to change in demand torque. At the same time there is a owing to the hysteresis controller due to the torque overshoot. The figure.1 & 2 shows the d-q axis flux and the figure.3 & 4 shows the d-q axis stator current.

VIII.REFERENCES

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IX.BIOGRAPHY

Mr.J.Vikramarajan received his Master degree in Power Electronics and Drives and Bachelor degree in Electrical and Electronics Engineering from VIT University, India. He has published several international research books and journals. His research interests are electrical machines, power electronic applications, power quality, power electronic converters and power electronic controllers for renewable energy systems.