SIMULATION OF INDIRECT VECTOR CONTROLED INDUCTION MOTOR

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1. Introduction

Use of Induction Motors has been enormous in many industries because they are cheap, simple, they require less maintenance, and they are rigid. Also, they offer wider range of applications. With research focused on developing the high-performance electrical drive for motors such as induction motor, new methods such as Space Vector Control (SVC), Direct Torque Control (DTC), Direct Flux Control (DFC) have proved better performance. Also, the already developed traditional V/F drive systems also works perfectly to have better torque response even at lower speed if the machine parameters are exact (more accurate) [1]. This means that calculation of motor parameters becomes crucial as all manufacturers do not provide them and provide only rated power, rated torque, efficiency, rated speed, power factor, rated voltage and current etc. Most known model is the single cage rotor model, and it can only predicts accurately starting from rated speed to the breakdown speed. To analyze starting and re-accelerating behavior, which single-cage rotor model cannot predict accurately, we need to have a double-cage rotor model which can gives accurate response of torque-slip behaviors even a lower speed [2-4].

The induction motor model is considered as a single-cage rotor model for direct online test (DOL) of an induction motor and parameters are calculated accordingly. The suitable motor design process includes selecting accurate motor dimensions, weight, and cost. Number of poles required should be chosen in between the required efficiency and the motor weight. Also, choice of rotor slot helps to avoid undesirable cogging, crawling and synchronous torques. For high-speed applications such as automotive, it is also desirable to limit the leakage reactance. The leakage inductance of the motor should not only depend on the required pull-out torque or the machine design specifications but also should depend on the harmonic ripple current, ac frequency, fundamental peak ac current etc. [5].

Parameter’s calculation and Direct On-line Test (DOL Test) of specified motor model was analyzed, designed, and tested in coursework 1. Results were satisfactory with some initial conditions slightly varied from the manufacturer’s specification, which in case of single cage rotor model is common. This scenario is also explained in these papers [2-4, 6-9]. Once the DOL Test gave results that were satisfactory, suitable PI controllers for current, speed, and field were designed using cascade-control design approach [5, 10-14]. These controller’s performance has been verified with respective plants for current, speed, and flux loops. They have been verified working well with respect to their performance, speed, and overall efficiency.

Now, in this coursework, vector control of induction motor will be performed, and performance of controllers designed earlier will be tested in cascade-loop to see the overall performance. Torque, Speed, Current, Flux etc. will be verified against their transient & steady-state behaviors under rated conditions. In Field-Oriented Control (FOC) of Induction Motor Drive system, Current Control Technology plays a very important role to drive a Pulse Width Modulation (PWM) Inverter. Constant Slip-Frequency and phase current closed control loop techniques are applied for low-speed applications. For Rotary Induction Motor drives, FOC schemes works very well where rotor field is held as constant [15-19].

2. Objective

The main objective of this coursework is to perform the vector control of the Induction Motor. In coursework 1, we have identified the motor parameters, performed a Direct-Online Test, verified results against manufacturer's specifications, and designed suitable current, speed, and field controllers. Now, in this coursework, the aim is to perform the control test of these controllers in IM model. We will use the cascade-control approach as it is very common and efficient. The Indirect Rotor Flux Orientation (IRFO) technique is used. The idea is to verify the performance of the designed controllers with the Induction Motor and to carry out some tests with rotor time constant variation, field control, and field weakening also as further work.

3. MATLAB Simulation Tests & Results

The simulation in MATLAB Simulink environment includes the IRFO vector control of the Induction Motor designed in the coursework 1. The IM motor is modelled in alpha-beta reference frame and the controllers are designed in dq reference frame. So, suitable conversion models to and from alpha-beta to dq are used. Similar vector-controlled models are also explained in these papers [15-22].

3.1 Testing of Current Loop Design

The current controller designed in coursework 1 with controller values of **Kp= 1.169** & **Ki=1072.44** is controlling the innermost current loop of bandwidth **200Hz**, and with a damping factor of **0.7**, which is enough to damp any current oscillations that may occur during the transient period. The following MATLAB MODELS are used to control the current loop.

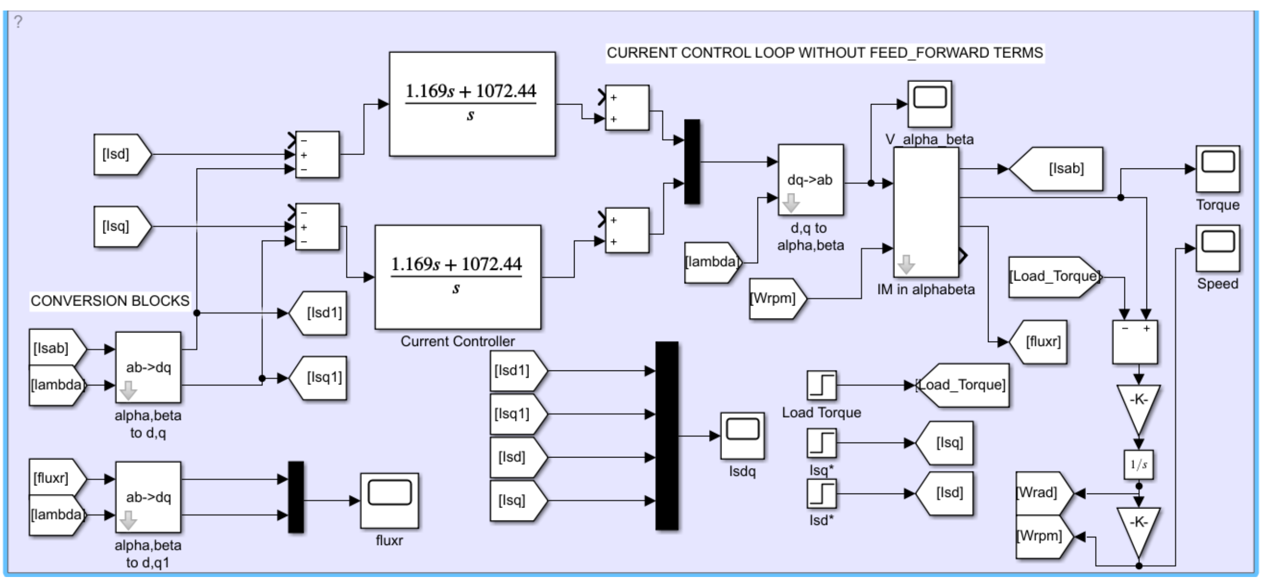


Figure 1: Current Control Loop (Without Feed-Forward Terms)

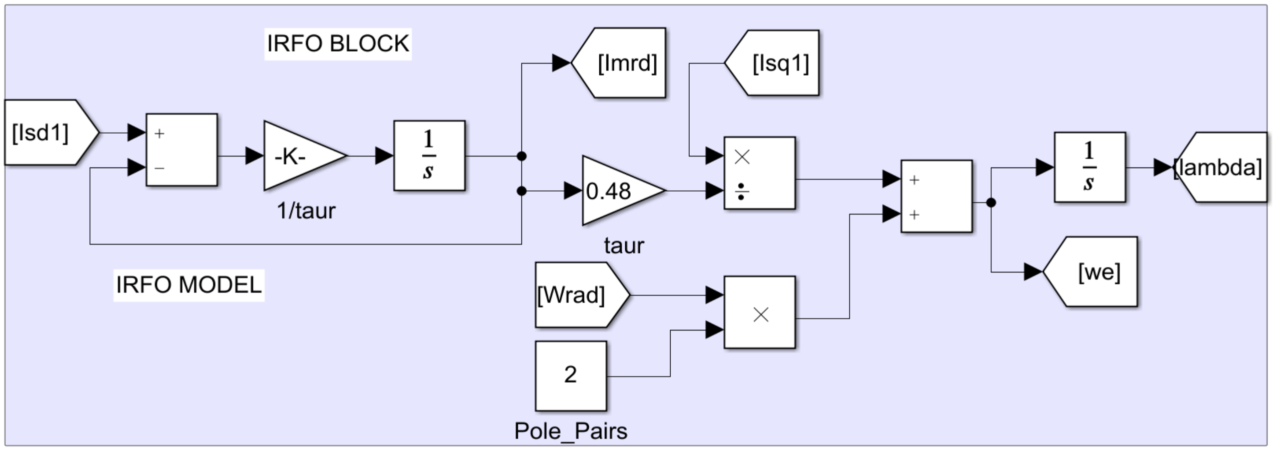


Figure 2: Indirect Rotor Flux Orientation (IRFO) Block

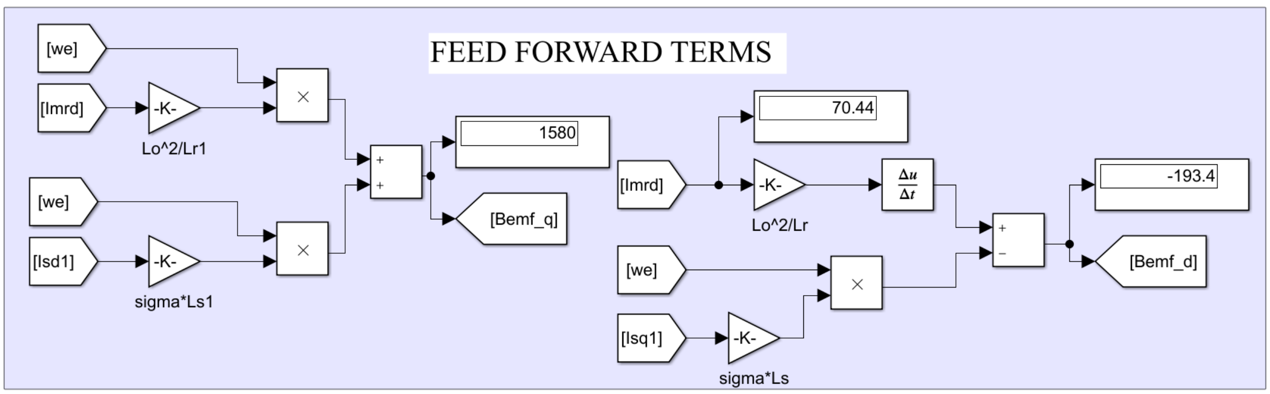


Figure 3: Voltage Feed-Forward Terms

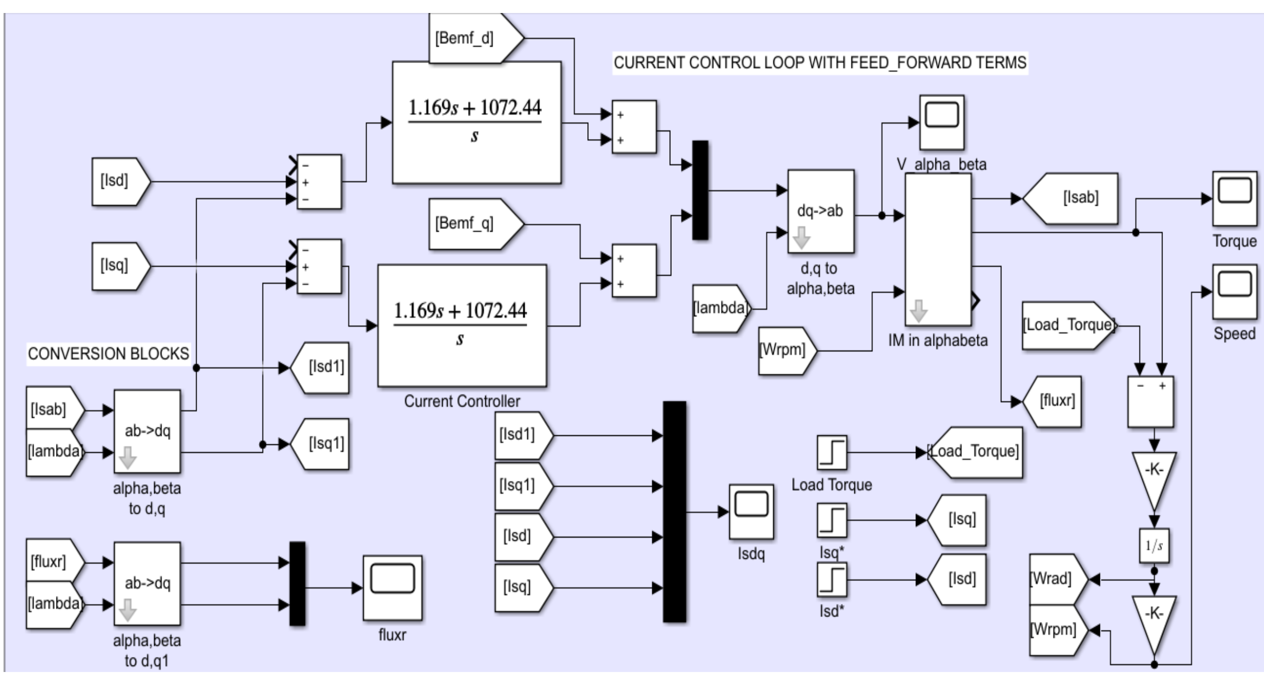
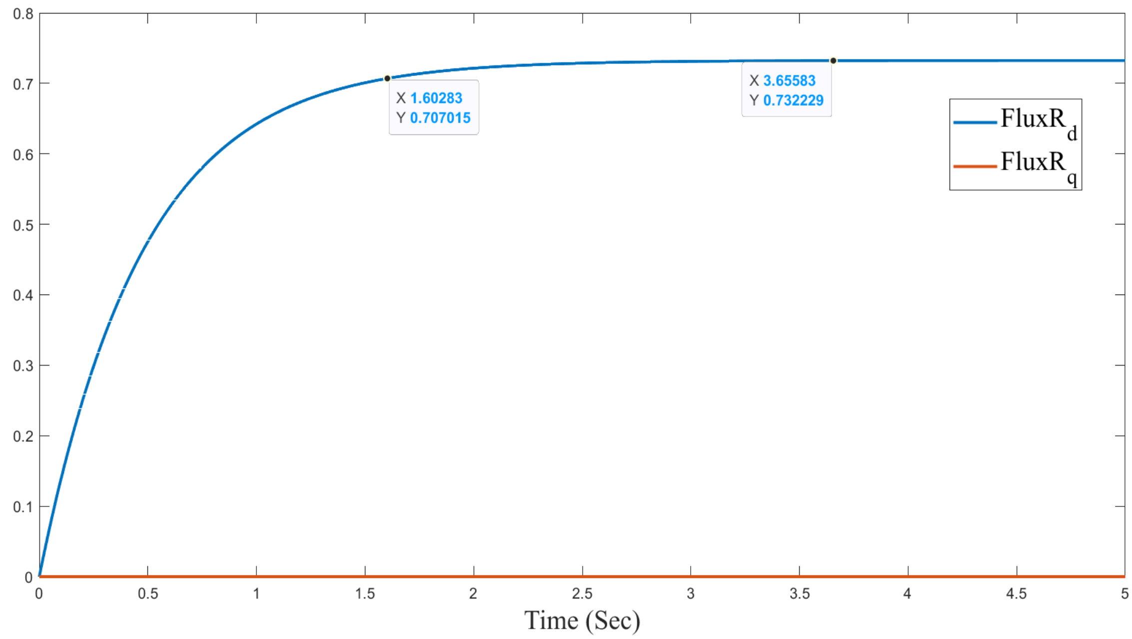


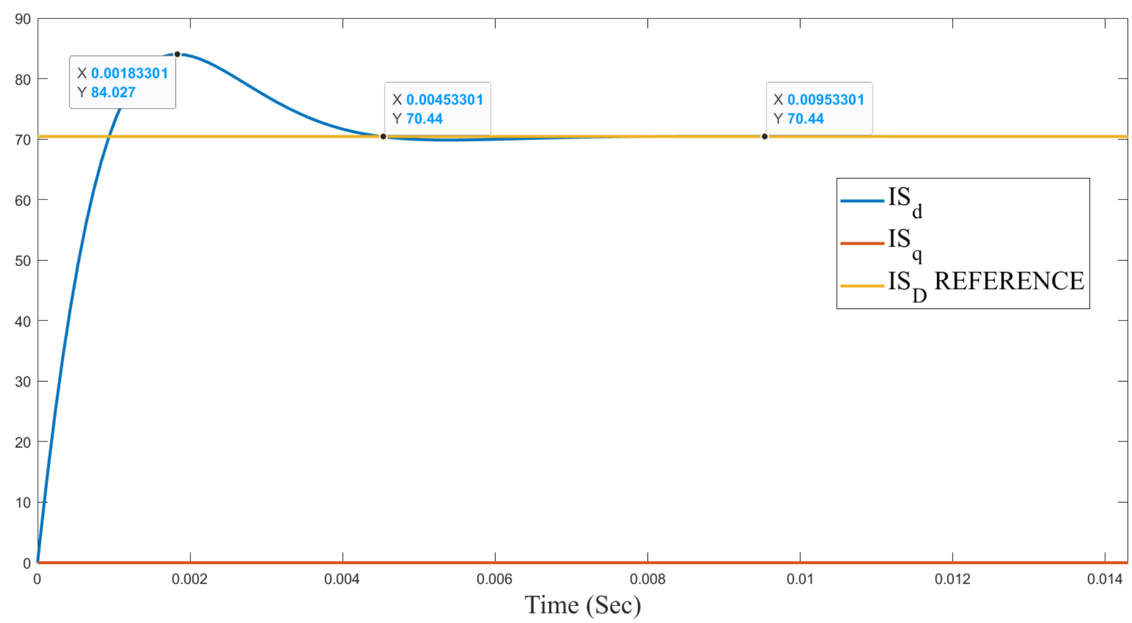
Figure 4: Current Control Loop (With Feed-Forward Terms)

The following test conditions are simulated to see the performance of the current control loop.

3.1.1 With Isd = Rated Value and Isq = 0

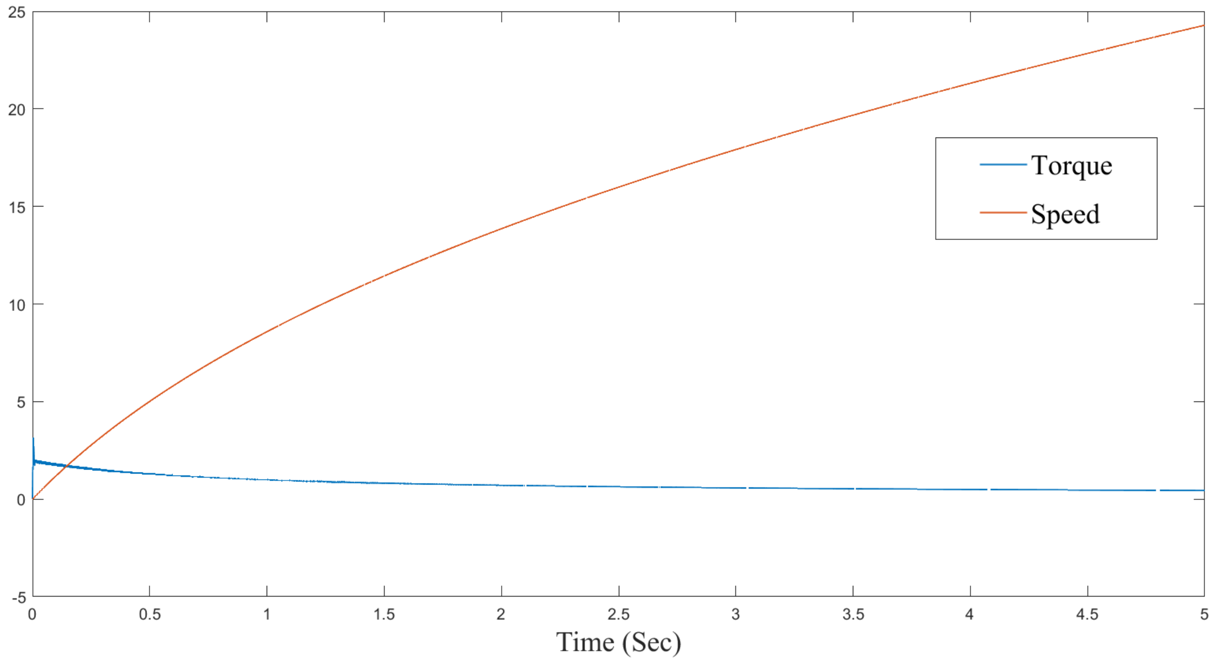
The idea is to give full rated Isd current, but zero Isq current to the machine to test the performance of IM with PI current controller. Following results are obtained without voltage compensation and speed loop.



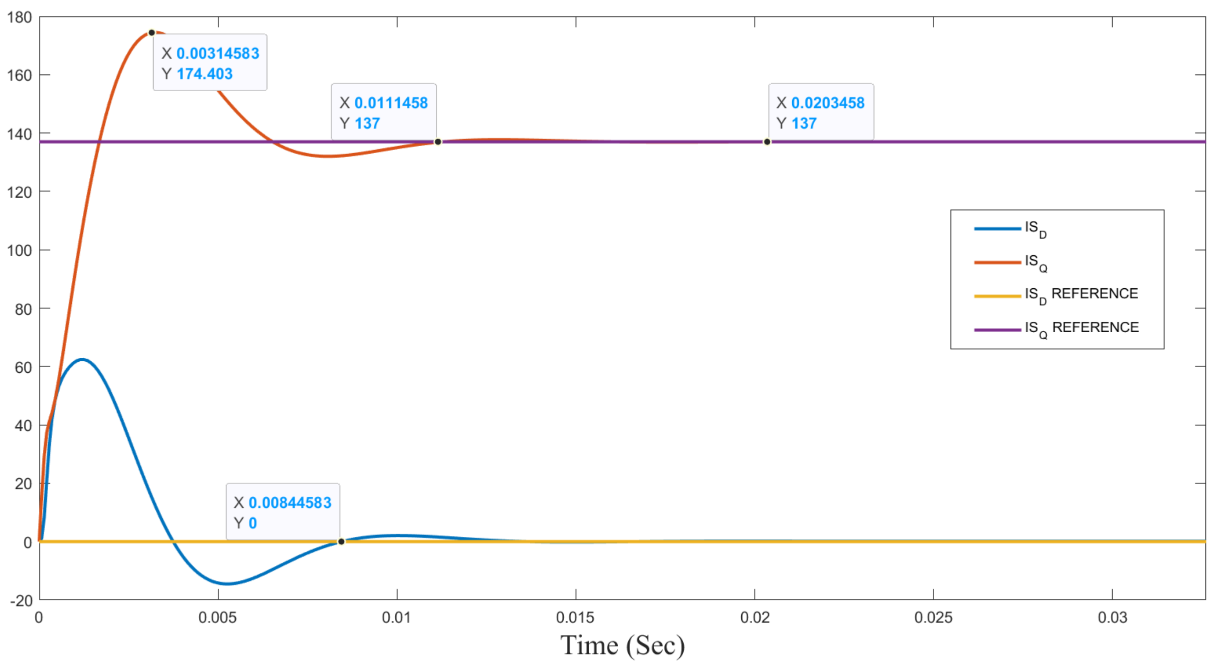


(With feed forward terms)

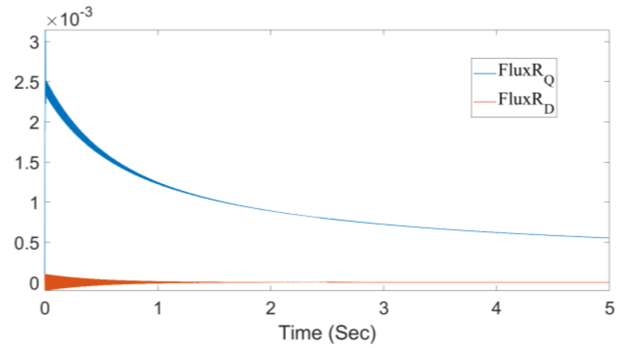
3.1.2 With Isq = Rated Value and Isd = 0



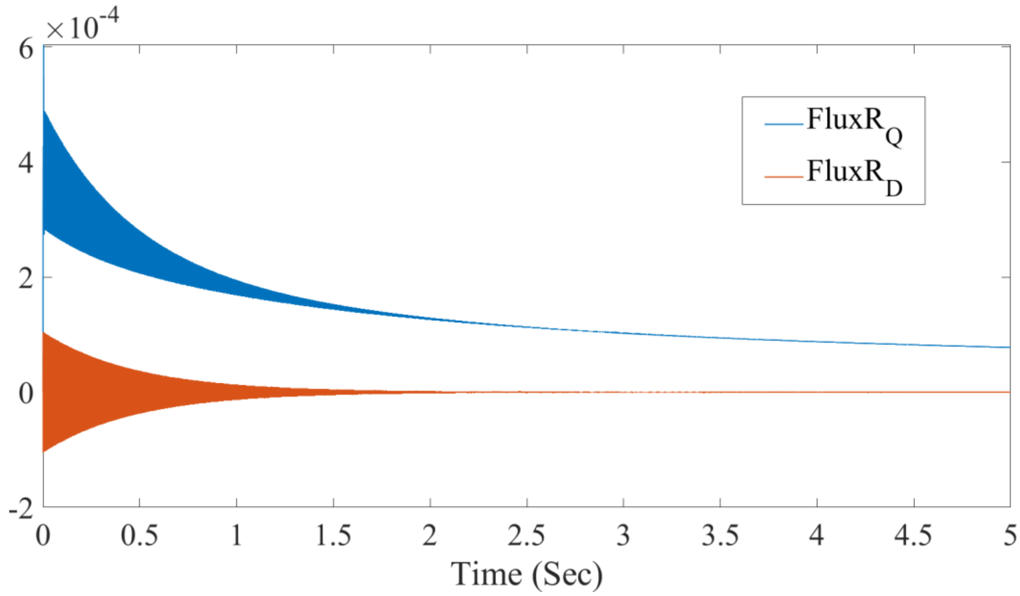
(without feed forward terms) (with feed forward terms, shapes are same, but values are very low)



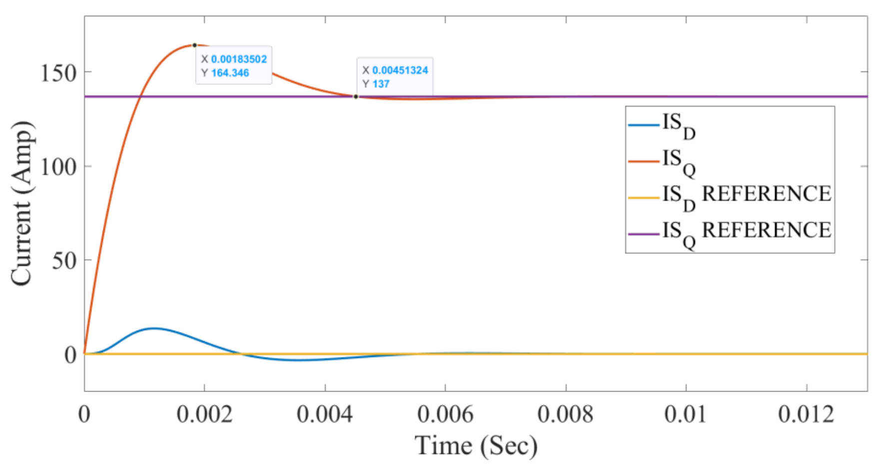
(Without feedforward terms)



Without feed forward terms

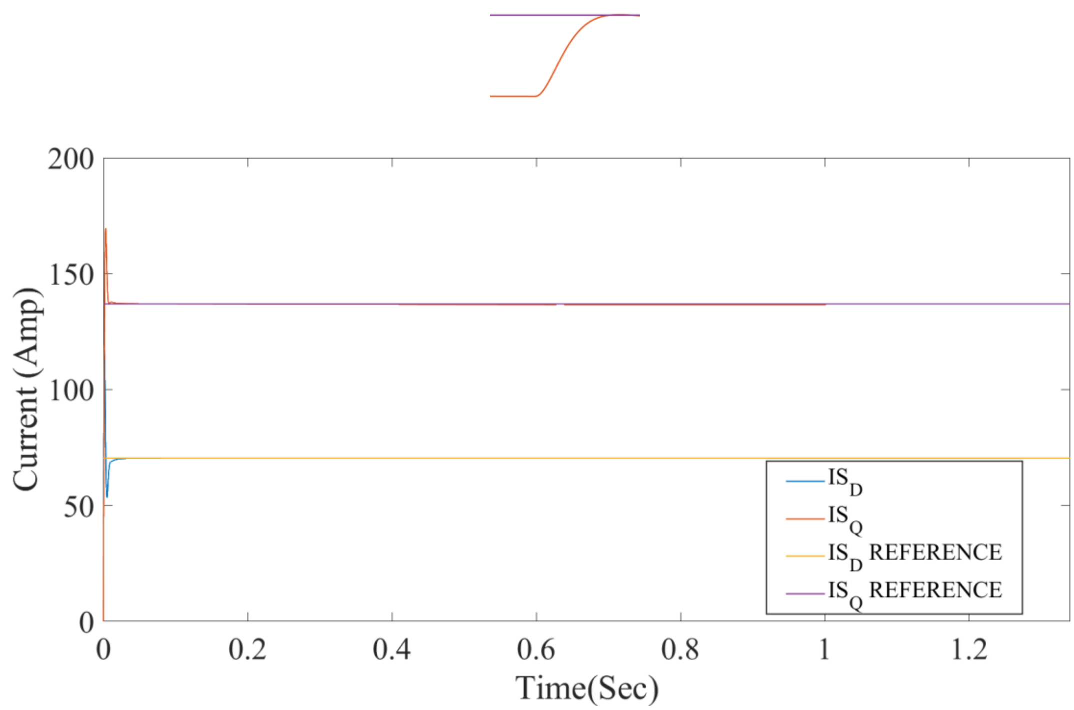


(with feed forward terms)

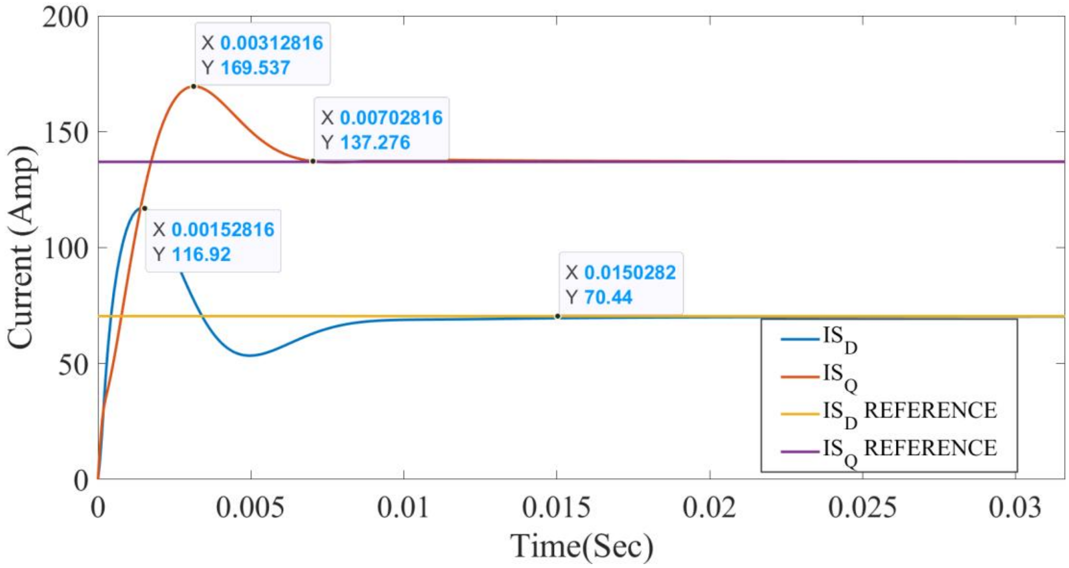


(with feed-forward terms)

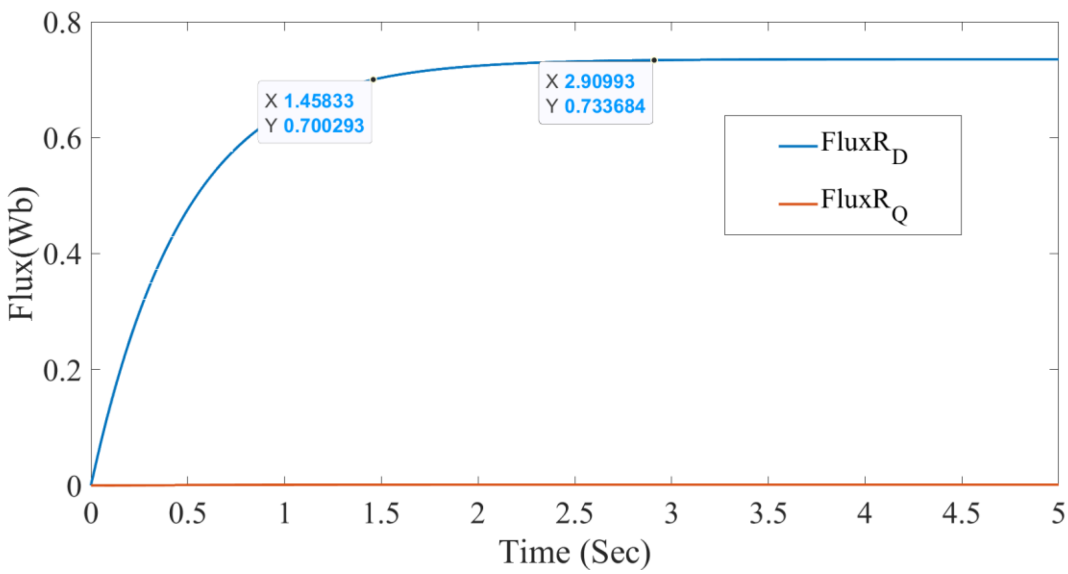
3.1.3 With Isq & Isd Rated



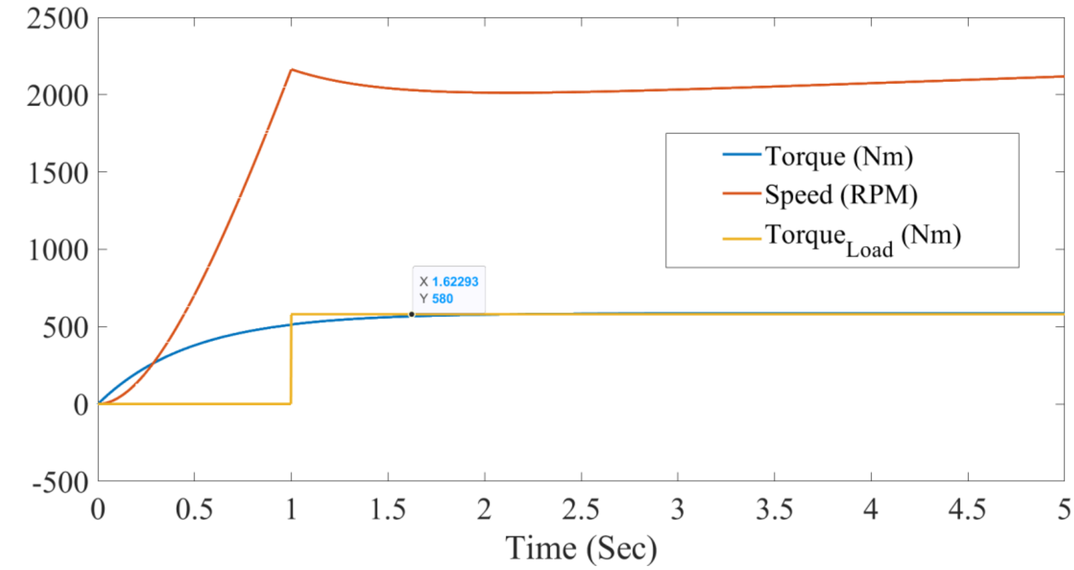
Without feed forward



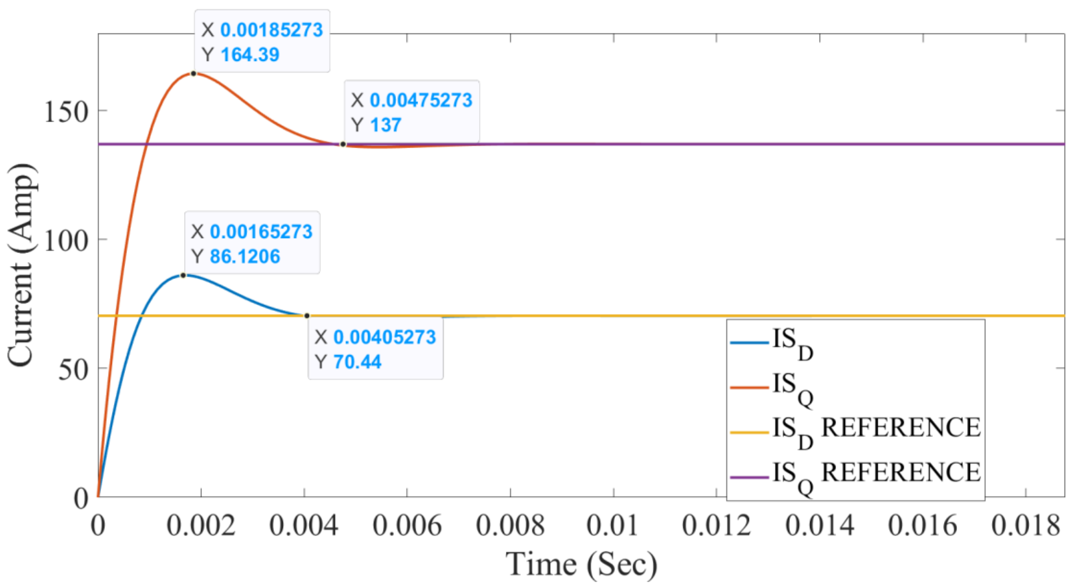
Without Feed forward



Without Feed Forward



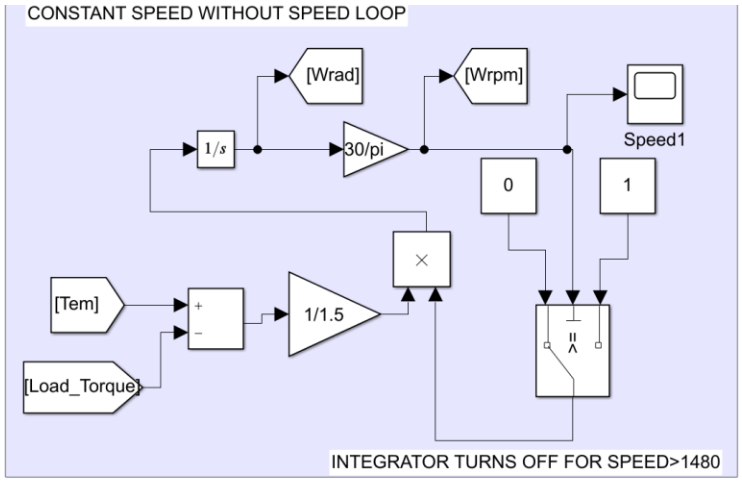
Without feedforward

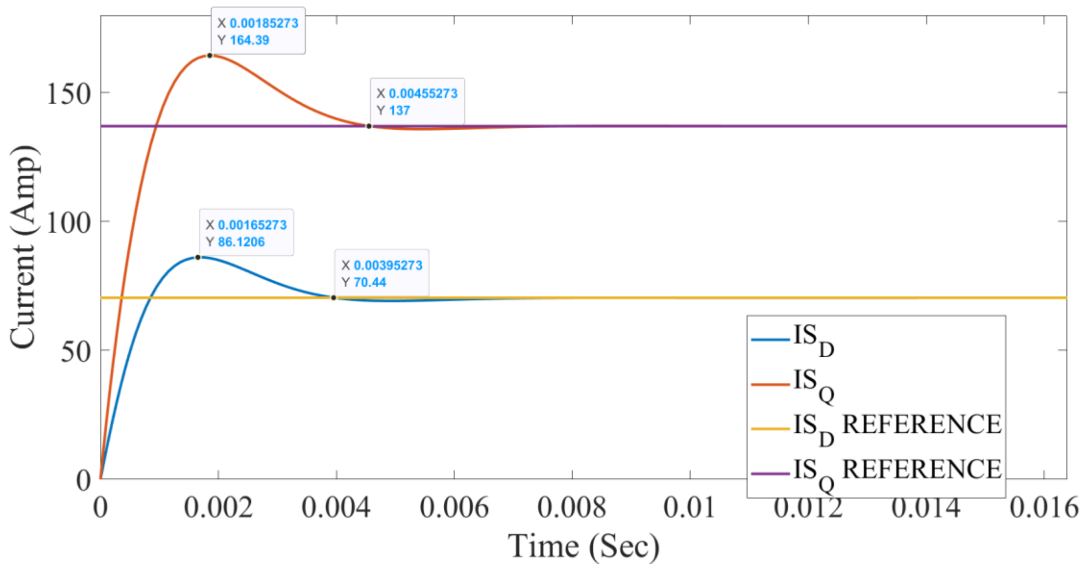


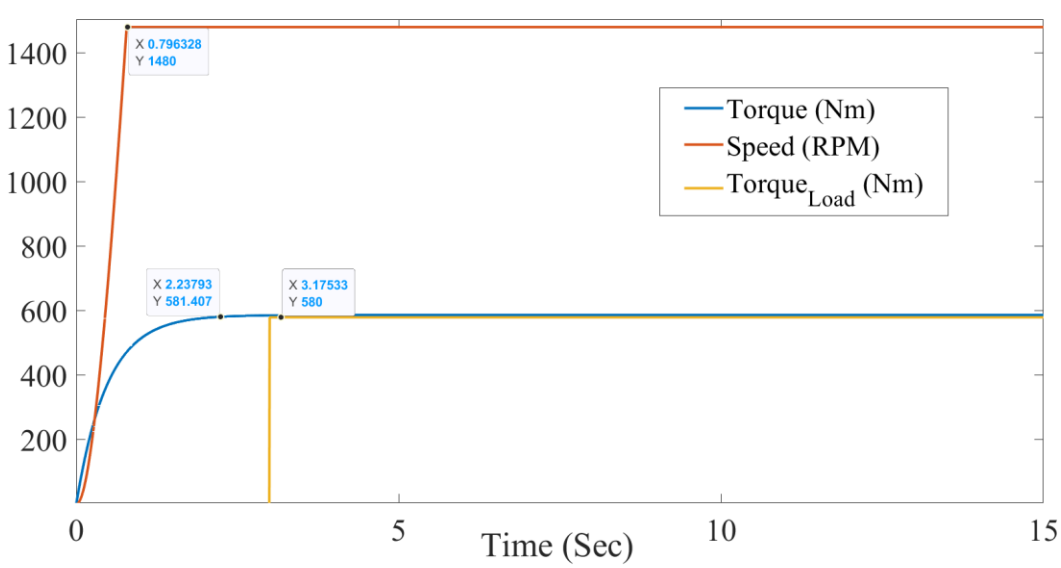
With feed forward, (other does not change much), reduces overshoot, improves transient response & settling time for current

3.1.4 With Feed-Forward Terms

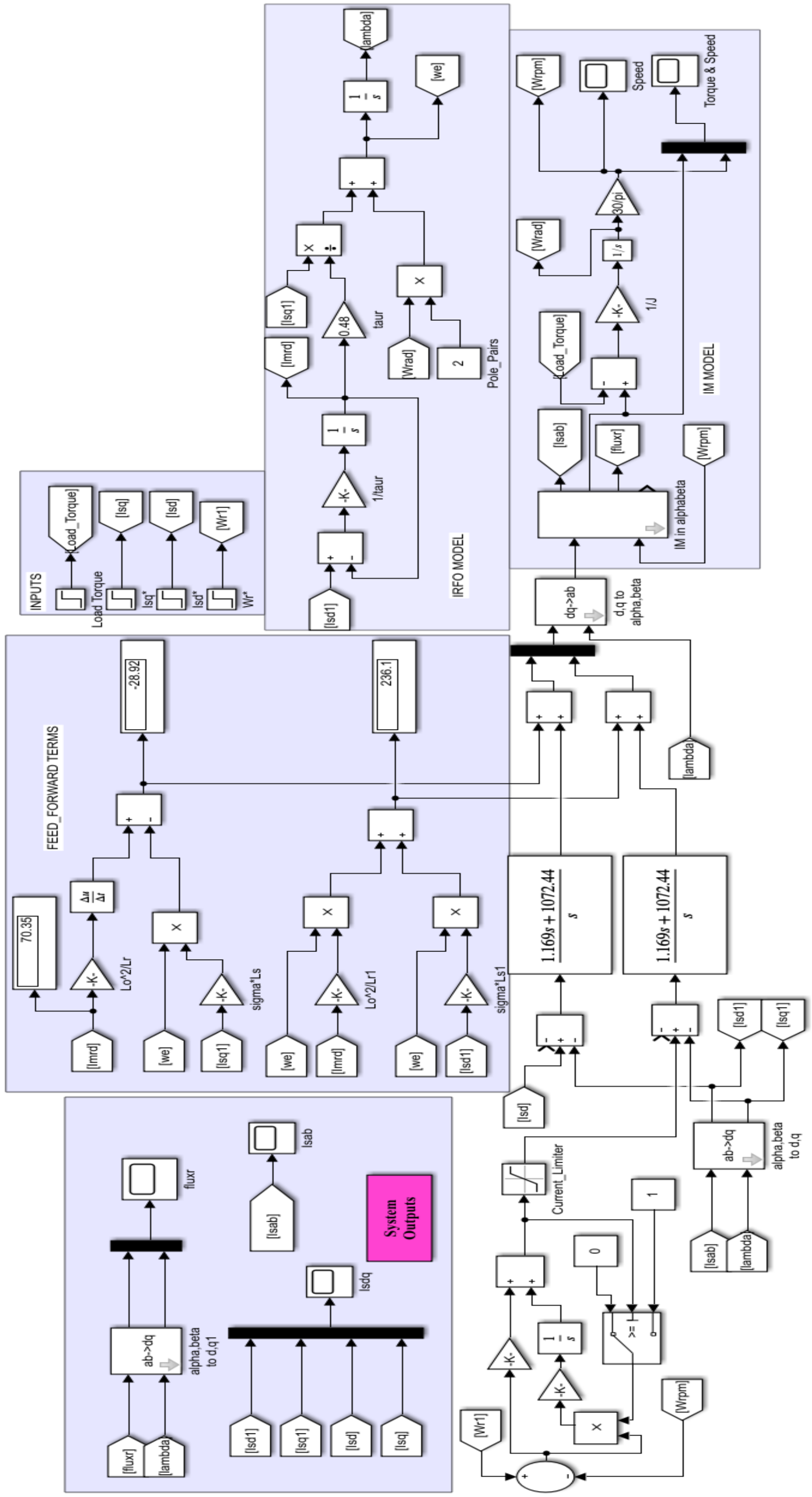
3.1.5 With Constant Speed


CONSTANT SPEED WITHOUT SPEED LOOP
[Wrad]
[Wrpm]
1/s
30/pi
Speed1
0
1
[Tem]
[Load_Torque]
1/1.5
INTEGRATOR TURNS OFF FOR SPEED>1480


X 0.00185273
Y 164.39
X 0.00455273
Y 137
X 0.00165273
Y 86.1206
X 0.00395273
Y 70.44
Current (Amp)
Time (Sec)
IS D
IS Q
IS D REFERENCE
IS Q REFERENCE


X 0.796328
Y 1480
X 2.23793
Y 581.407
X 3.17533
Y 580
Torque (Nm)
Speed (RPM)
Torque Load (Nm)
Time (Sec)

3.2 Testing of Speed Loop Design


INPUTS
Load Torque
Isq*
Isd*
Wr*
[Load_Torque]
[Isq]
[Isd]
[Wr1]
IRFO MODEL
[Isd1]
1/taur
[Imrd]
[Isq1]
0.48
taur
[Wrad]
2
Pole_Pairs
[we]
[lambda]
IM MODEL
IM in alphabeta
[Isab]
[fluxr]
[Wrpm]
[Load_Torque]
1/J
1/s
30/pi
[Wrad]
[Wrpm]
Speed
Torque & Speed
FEED_FORWARD TERMS
70.35
Lo^2/Lr
sigma*Ls
-28.92
Lo^2/Lr1
sigma*Ls1
236.1
[Imrd]
[we]
[Isq1]
[Isd1]
1.169s + 1072.44
s
dq->ab
d,q to alpha,beta
[lambda]
[Isd]
ab->dq
alpha,beta to d,q
[Isab]
[lambda]
Current_Limiter
0
1
[Wr1]
[Wrpm]
ab->dq
alpha,beta to d,q1
[fluxr]
[lambda]
flux
[Isab]
Isab
Isdq
[Isd1]
[Isq1]
[Isd]
[Isq]
System Outputs

[1] Y. Liyong, P. Xiaolin, and L. Zhengxi, "Induction motor electrical parameters identification using RLS estimation," in *2010 International Conference on Mechanic Automation and Control Engineering*, 26-28 June 2010 2010, pp. 3294-3297, doi: 10.1109/MACE.2010.5535653.
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