

Feedback Control System of SCORA-ER14 Robot in SIMULINK Platform

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Abstract— In this paper the feedback control system of SCORA-ER14 robot is implemented using SIMULINK environment in MATLAB. The control structure of a SCORA-ER14 robot is like any other SCARA type robot, which is essentially independent joint control. Here the feedback from the output side of the each individual Axes is taken and the entire control scheme is governed by PID control law. The parameters of proportional, integral and derivative gains are properly tuned to achieve stable performance by the robot. The control system is also tested using different signals like step and ramp as input.

Keywords— SCARA Robot, SCORA-ER14, Control, Feedback, PID, SIMULINK.

I. INTRODUCTION

The SCARA type robots are very popular in industry application due to its ability to manipulate things in a very flexible manner with its four degrees of freedom [1]. But in assembly operations positioning error is a critical issue which needs to be addressed properly [2]. There could also be some uncertainties about the model of the robot which makes the open loop control inefficient [3]. The decoupling control by using the inverse dynamics is generally very popular [4]. Although a good knowledge about the dynamics helps the control model of the robot but the compensation of model uncertainties is always necessary [5]. Also the large dynamic disturbances are a key factor for the implementation of control law [6]. Here the independent joint control model of the SCORA-ER14 robot is based on the actuator dynamics of the joints and the control law taken as the proportional, integral and derivative control. The position feedback is taken from the output side which is mixed with the input signals to generate desired stable output by tuning the PID parameters. The control of the first two joints Axis 1 and Axis 2 are discussed in a single section as they are similar in nature. Then the 3rd and 4th joints i.e. Axis 3 and Axis 4 are discussed in separate two sections. In each section the open-loop equation of the axis is shown which is based on the actuator dynamics. Then the feedback control circuit diagram along with the SIMULINK block diagram is depicted. The output from the SIMULINK model is plotted for step and ramp outputs in two different graphs to visualize how the output signal has followed the input signal for particular values of PID parameters, responsible for a stable output. The nature of the response curves is discussed briefly in the subsequent concluding section to highlight the significance of this work.

II. CONTROL SCHEME OF AXIS1 AND AXIS2

The open loop transfer function:
$$\frac{\Theta_1(s)}{V(s)} = \frac{K \cdot K_m / R}{P_m(s) P_l(s) - R^2 + n \cdot K \cdot K_m \cdot K_b / R}$$

The control law is defined as $V(s) = n \cdot [K_p + s \cdot K_v + K_i / s] (\theta_1^d - \theta_1)$

Where,

$\Theta_1(s)$ = rotation along axis 2, $V(s)$ = voltage applied, $P_m(s) = J_m \cdot s^2 + K$, $P_l(s) = J_l \cdot s^2 + K$,

J_m = moment of inertia at motor side, J_l = moment of inertia at load side, K = stiffness, K_m , K_b = constants,

R = motor resistance, n = gear ratio, K_p = proportionality constant, K_v = differential constant, K_i = Integral constant.

The feedback control circuit diagram of Axis1 is given in Fig.1 below:

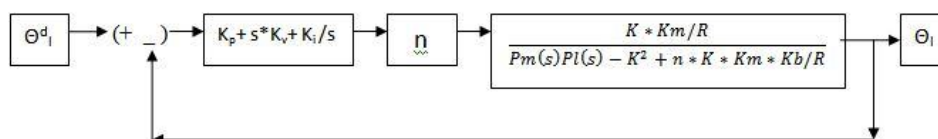


Fig.1 Feedback control circuit diagram of Axis 1

MATLAB/Simulink Results: The above block diagram is simulated in MATLAB/Simulink for two different inputs of Θ_1^d .

- i) Step Input,
- ii) Ramp Input.

The Simulink diagram is shown in Fig.2.

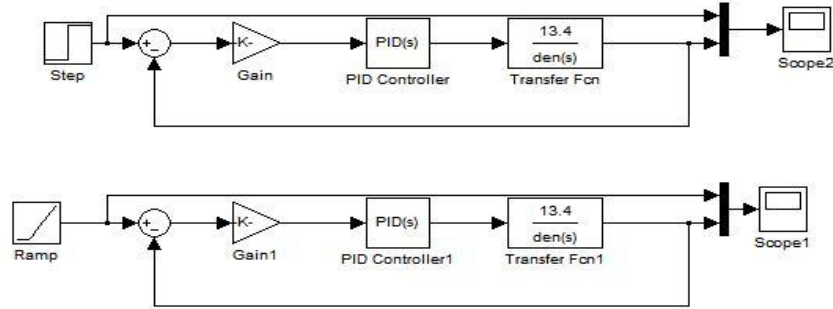


Fig.2: Simulink diagram of Axis 1, feedback control circuit.

Results of Axis 1:

The results of step and ramp input are shown in Fig.3 and Fig.4 respectively. Given below are the values of different parameters considered for simulation.

$J_m=0.045$ N-m, $J_l=0.045$ N-m, $K=1000$ N/m, $K_m=0.047$ N-m/A, $K_b=0.047$ v-s/rad, $R=3.5$ Ohm, $n=160$.

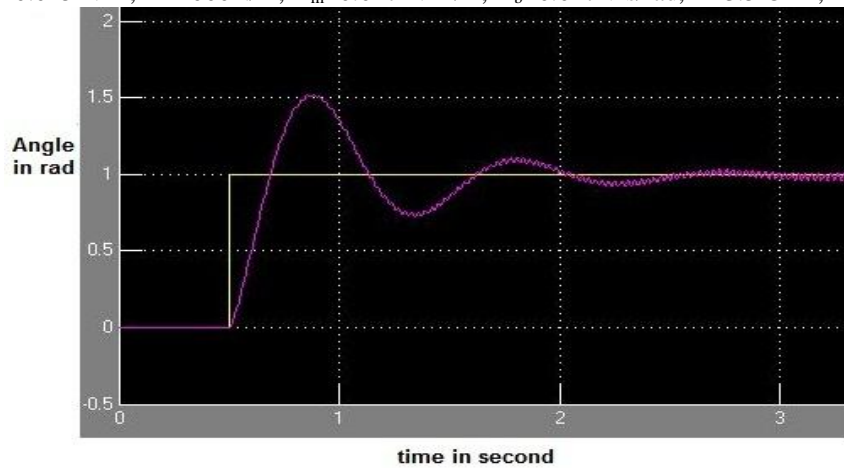


Fig.3: Output of the feedback control for step input for Axis1 (For $K_p=2$, $K_v=0.06$, $K_i=1$).

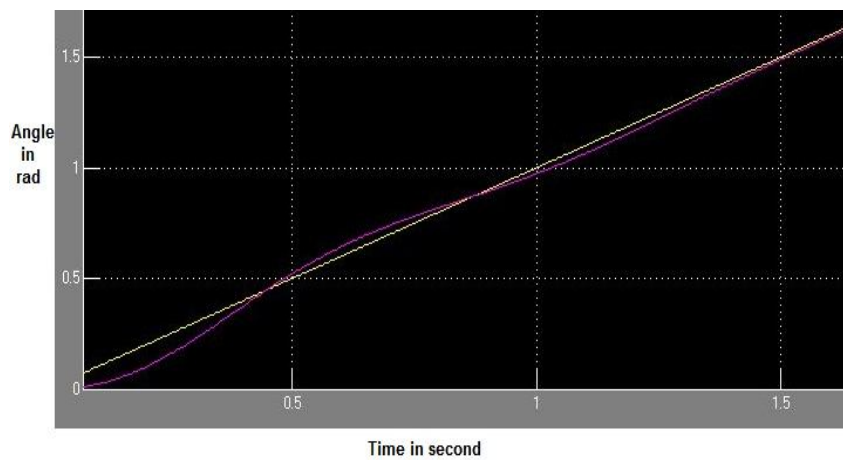


Fig.4: Output response of the feedback control for ramp input for Axis.2 (For $K_p=2$, $K_v=0.06$, $K_i=1$).

III. CONTROL SCHEME OF AXIS 3

The open loop transfer function is:

$$\frac{D(s)}{V(s)} = \frac{K_m \cdot l / R}{r \cdot J_m \cdot s^2 + K_m \cdot K_b \cdot r / R}$$

The control law is defined as $V(s) = (r/l) \cdot (D^d(s) - D(s)) \cdot [K_p + s \cdot K_v + K_i/s]$

Where,

R= motor resistance, K_m, K_b = constants, J_m = moment of inertia at the motor side, r= gear ratio, l= constant.
D(s)= Translation along axis 3, V(s)= Applied voltage, K_p = proportionality const., K_v = diff. const., K_i = Integral constant.

The feedback control circuit diagram of Axis3 is given in Fig.5 below:

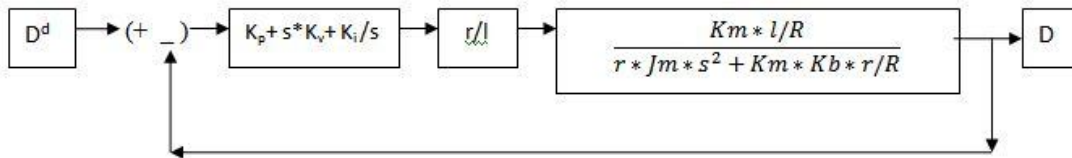


Fig.5: Feedback control circuit diagram of Axis3

MATLAB/Simulink Results: The above block diagram is simulated in MATLAB/Simulink for two different inputs of D^d ,

- i) Step Input,
- ii) Ramp Input.

The Simulink diagram is shown in Fig.6.

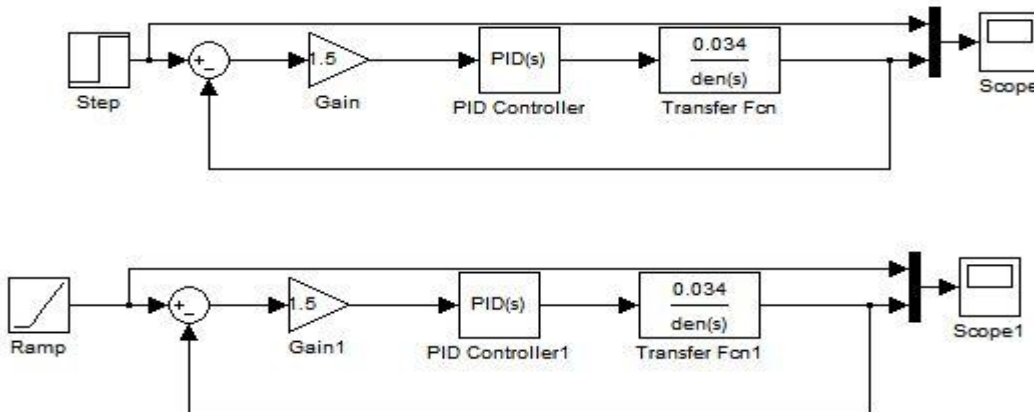


Fig.6: Simulink diagram of Axis 2, feedback control circuit.

Results of Axis 3:

The results of step and ramp input are shown in Fig.7 and Fig.8 respectively. Given below are the values of different parameters considered for simulation.

$R=3.5\text{ohm}$, $K_m=0.047\text{ N-m/A}$, $K_b=0.047\text{ v-s/rad}$, $J_m=0.0002\text{N-m}$, $l=0.016/2\pi\text{ m}$, $r=81/21$.

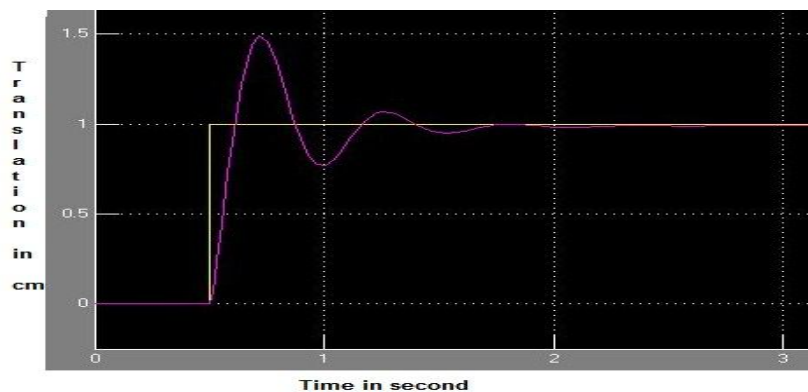


Fig.7: Output response of the feedback control for step input for axis 3 (For $K_p=2000$, $K_v=100$, $K_i=1000$)

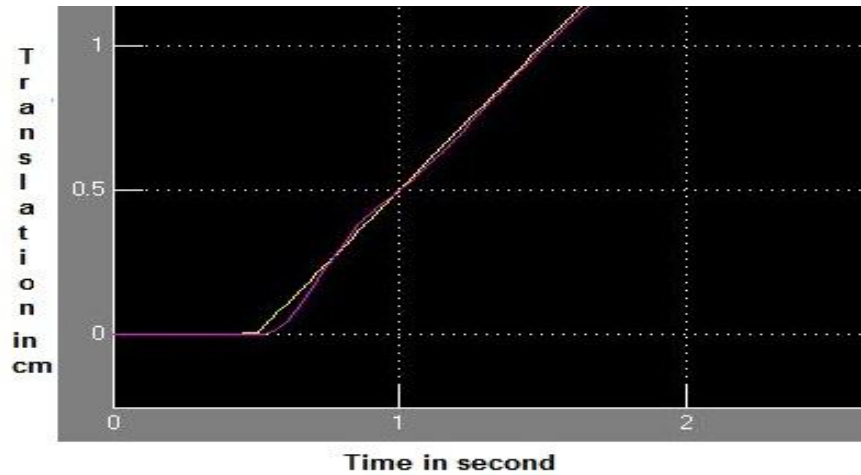


Fig.8: Output response of the feedback control for ramp input for axis 3(For $K_p=2000$, $K_v=100$, $K_i=1000$)

IV. CONTROL SCHEME OF AXIS 4

The open loop transfer function is:
$$\frac{\theta_1(s)}{V(s)} = \frac{Km/R}{r*Jm*s^2 + s*Km*Kb*r/R} \quad (4.21)$$

The control law is defined as $V(s) = r*(\theta^d_1(s) - \theta_1(s)) * [K_p + s*K_v + K_i/s]$

Where,

R=motor resistance

K_m, K_b =constants

Jm=moment of inertia at the motor side

r=gear ratio

$\theta_1(s)$ =Translation along axis 4.

V(s)=Applied voltage.

K_p =proportionality const.

K_v =differential constant.

K_i =Integral constant.

The feedback control circuit diagram of Axis 4 is given in Fig.9 below:

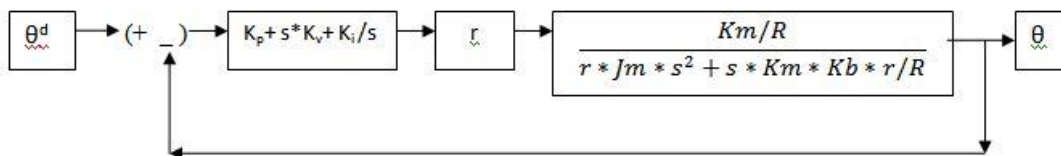


Fig.9: The feedback control circuit diagram of Axis 4

MATLAB/Simulink Results: The above block diagram is simulated in MATLAB/Simulink for two different inputs of θ^d ,

- i) Step Input,
- ii) Ramp Input.

The Simulink diagram is shown in Fig.10.

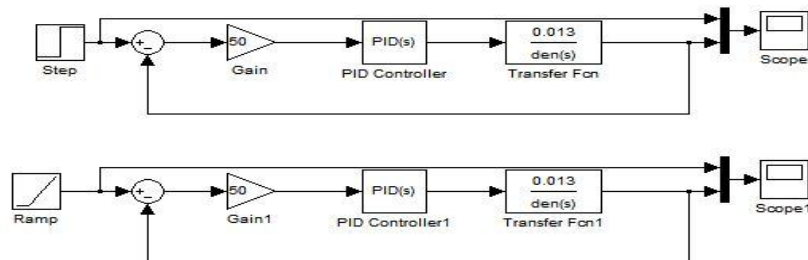


Fig.10: Simulink diagram of Axis 4, feedback control circuit.

The results of step and ramp input are shown in Fig.11 and Fig.12 respectively. Given below are the values of different parameters considered for simulation.

$$R=3.5\text{ohm}, K_m=0.047 \text{ N-m/A}, K_b=0.047 \text{ v-s/rad}, J_m=0.0003\text{N-m}, r=50.$$

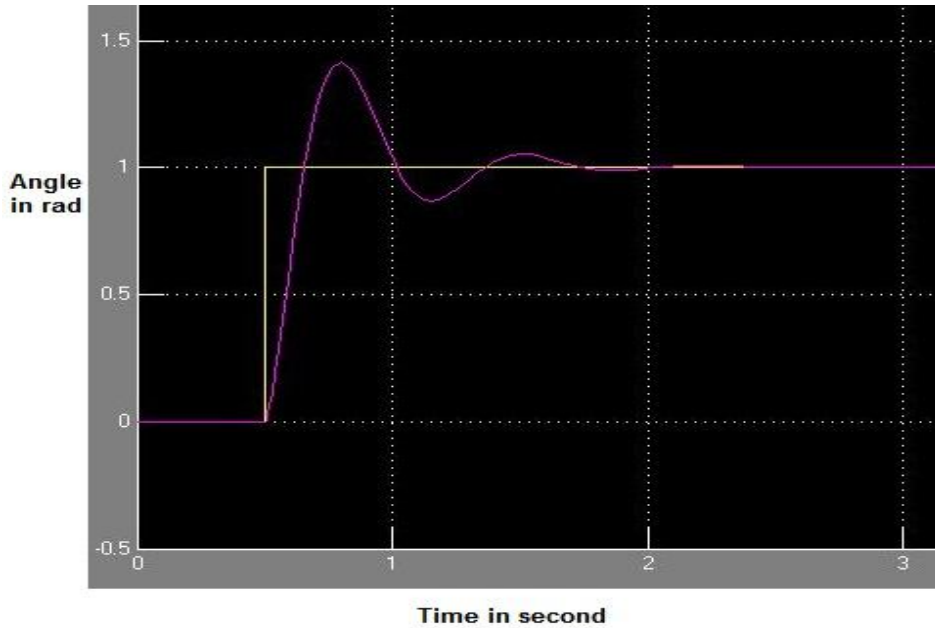


Fig.11 : Output response of the feedback control for step input for axis 4(For $K_p=2$, $K_v=0.01$, $K_i=1$)

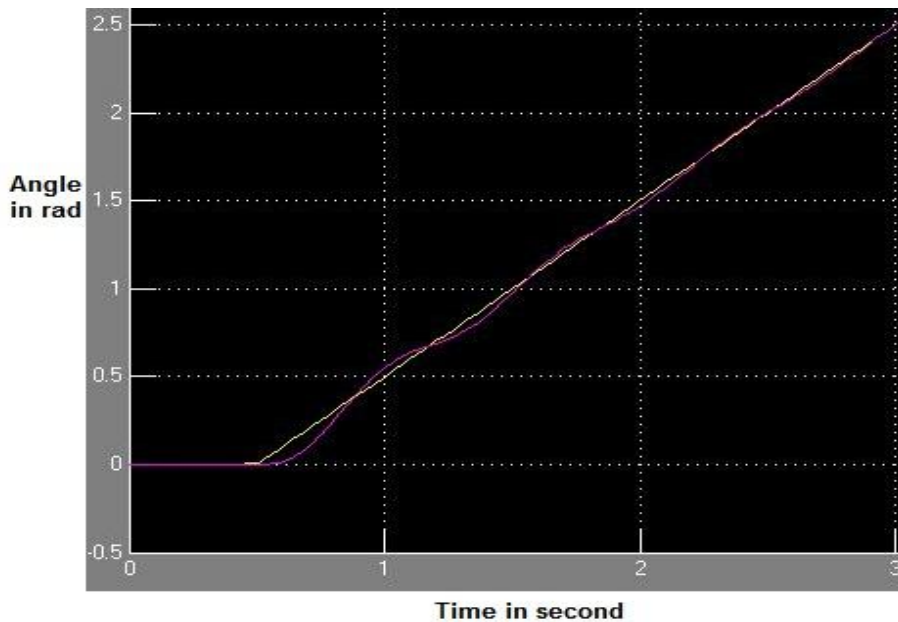


Fig.12: Output response of the feedback control for ramp input for axis 4(For $K_p=2$, $K_v=0.01$, $K_i=1$)

V. CONCLUSION

From the open loop transfer function of each joint we have applied feedback controller taking the control law as PID. Then the output response is plotted for two types of inputs, one is step input and the other is ramp input. The values of K_p , K_v and K_i are tuned by trial and error method to get a stable response. We have ignored here the viscosity/frictional constants of the motor and load side to be very small, also the L/R value is also neglected, where L is the inductance and R is the resistance of the motor. The actuator dynamics plays an important role in the control structure, adding disturbances to the system. Here this disturbance part is avoided to make the system ideal. Although the PID values set here might need to be readjusted for getting stable response in presence of dynamic disturbances.

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