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CONTROL OF HYDRAULIC SERVO-ACTUATORS USING AN AUTOMATED ALGORITHM DESIGN

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One step further in the automatic control design - 3 October 2005

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Control Design of *almost-linear plants*

Steps for Control Design:

1. *"Control design requirement specifications"*
   feedback control frequency band

2. Linear model (Simplified Model) and State Observer with a frequency pass band, assuring:
   a) *norm-bounded* plant-model uncertainty
   b) accurate modelling within the operating range

3. Design of a Fine Model that models accurately the plant within a frequency band 10X larger than the simplified one

Steps for Control Design (cont.):

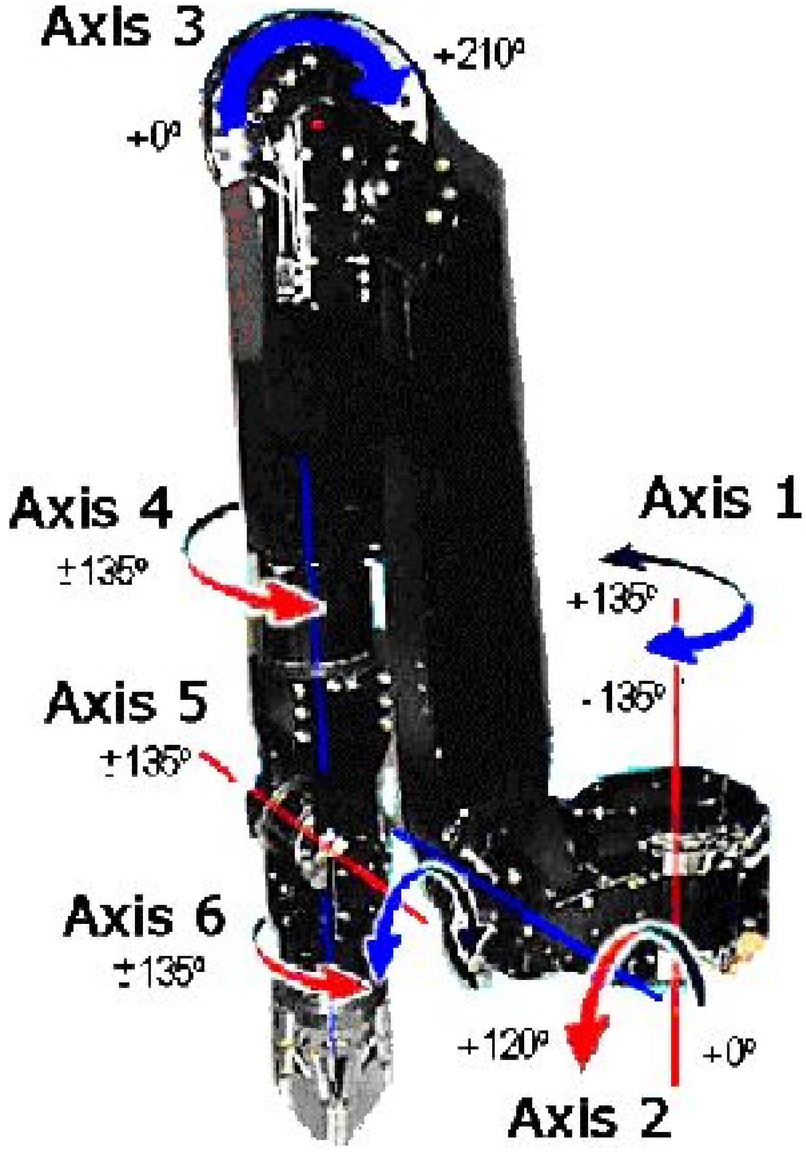
4. Assessment of 2b) by comparing the Fine Model through the State Observer and the Simplified Model

5. Design of a feedback control based on the Simplified Model without taking the plant-model uncertainty into account

6. Performance tuning and assessment by means of EicasLab simulator, using the Fine Model to simulate the plant

MAESTRO Hydraulic Arm

- hydraulic arm for heavy load work in nuclear power plants
- 6 axes (with position and pressure sensors)
- grip for manipulation of objects

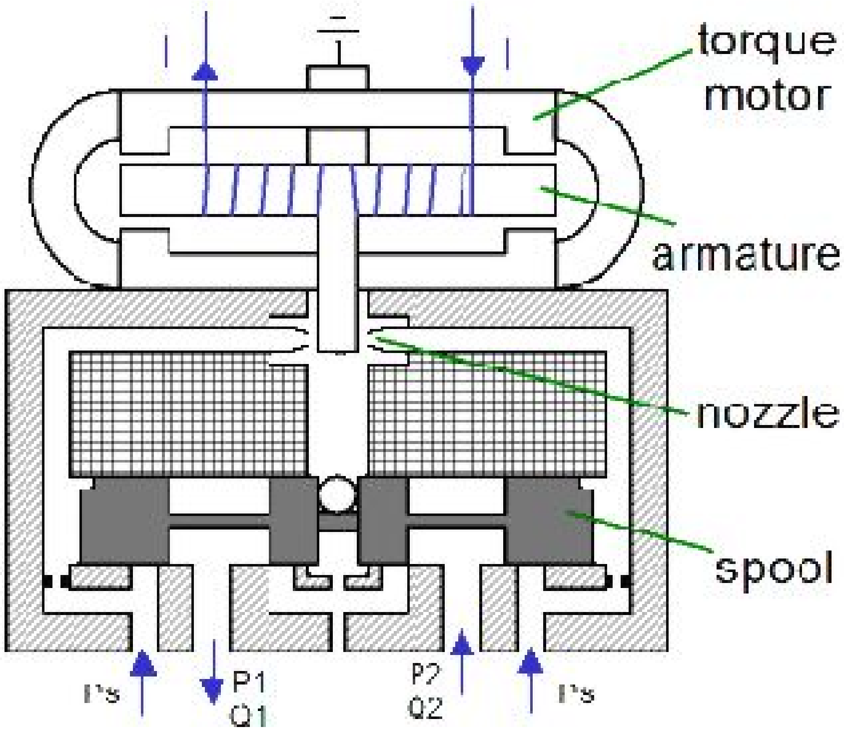


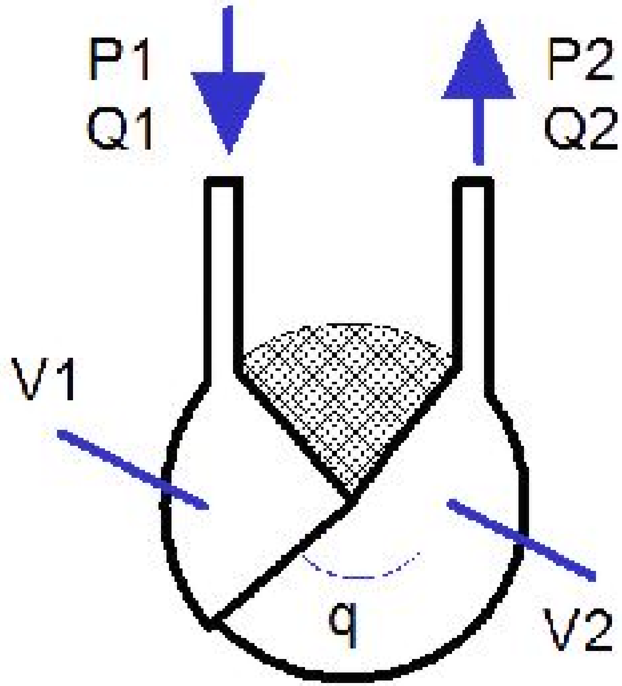
Characteristics

Number of axes		6 + gripper
Load Capacity	(max.)	1000 N
	Gripper	2500 N
Rotation range	Axis #1	-135° to +135°
	Axis #2	0° to +120°
	Axis #3	0° to +210°
	Axis #4	-135° to +135°
	Axis #5	-135° to +135°
	Axis #6	-135° to +135°
Gripper range		150 mm
Weight		90 kg
Hydraulic pressure		120, 210 and 260 bars

Combination of electrical, hydraulic and mechanical parts

<u>Hydraulic servo-actuator</u>: servo-valve and rotary actuator





Dynamic model of the hydraulic servo-actuator:

$$Q_L = K_{qi}\, i$$

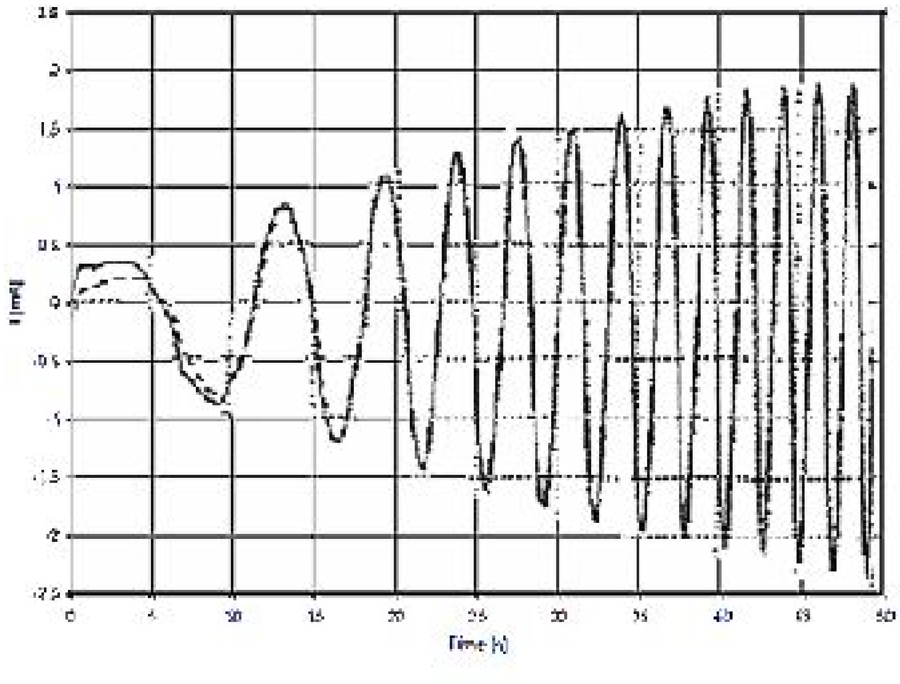
$$\frac{C_y}{4b_e}\dot{P}_L + C_{tm}P_L = Q_L - D_m\dot{q}$$

$$J_m\ddot{q} + C_{fv}\dot{q} + C_{fs}\,sign(\dot{q}) = D_mP_L$$

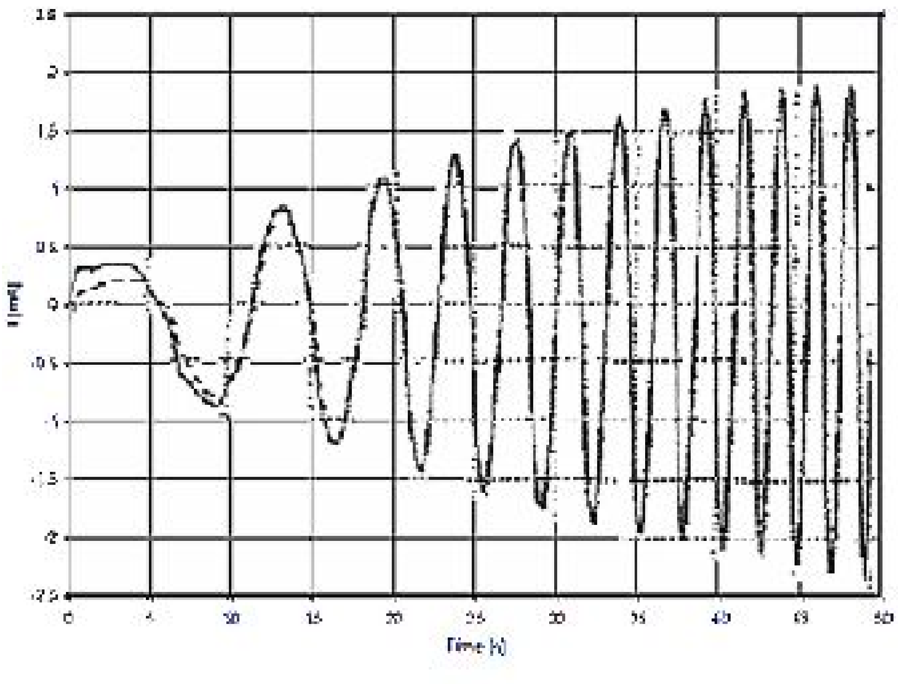
q	Angular position of motor shaft;
P_L	Pressure difference across the motor ($P_L=P_1-P_2$);
Q_L	Average flow for the two chambers;
i	Electric current for command;
D_m	Volumetric displacement of the motor;
C_y	Motor's total compressed volume;
b_e	Effective bulk modulus of the system;
C_{tm}	Inter-chamber leakage coefficient;
J_m	Moment of inertia of the motor and load;
C_{fv}	Viscous friction coefficient;
C_{fs}	Static friction coefficient;
K_{qi}	Servo-valve gain.

Dynamic model simulations

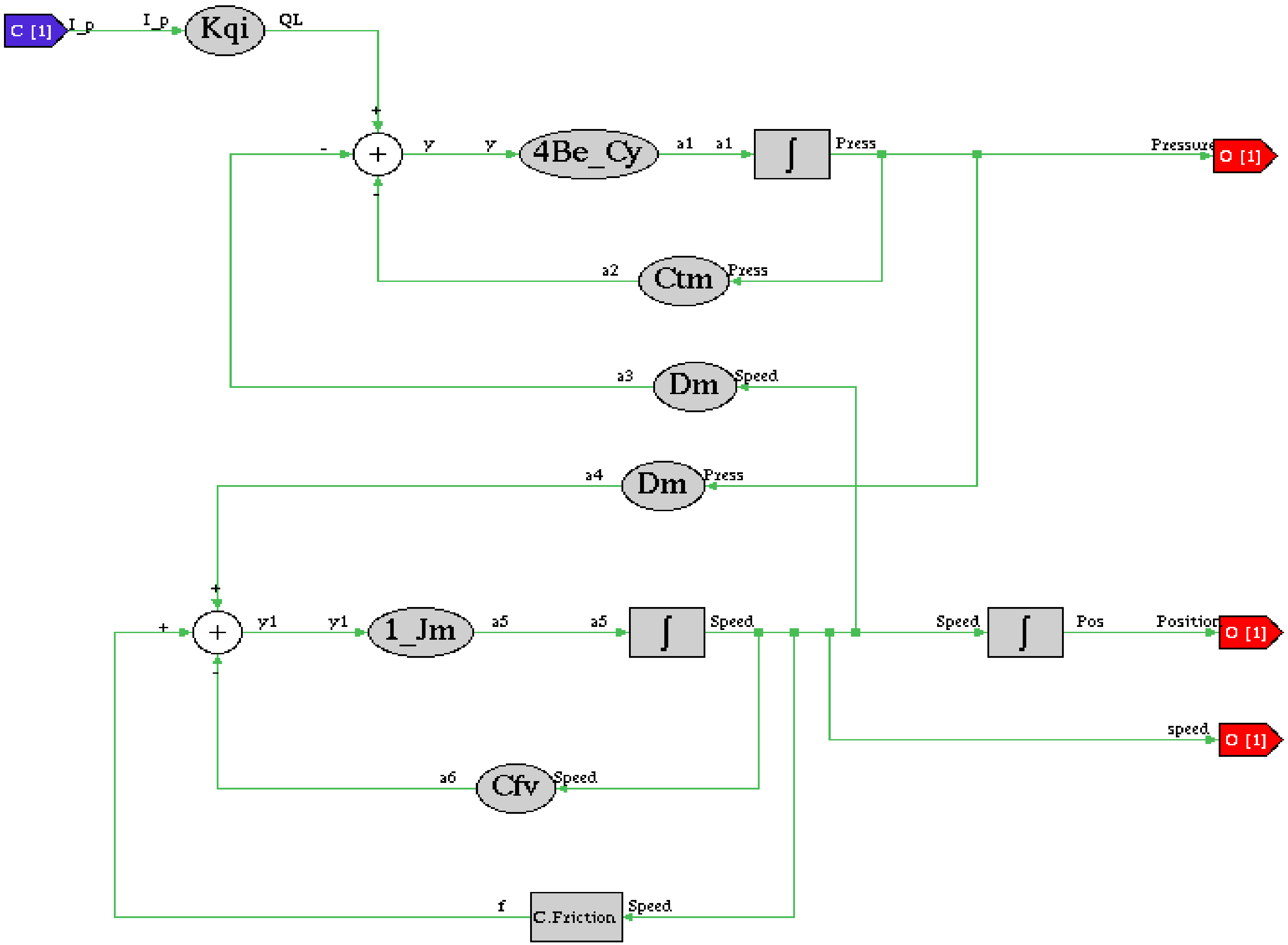
Current



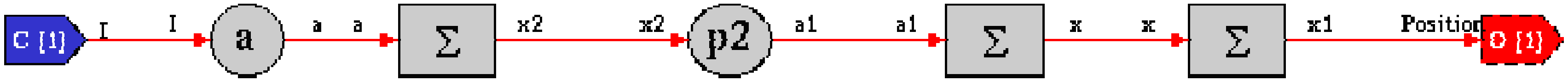
Pressure



Fine Model


C [1]
I_p
I_p
Kqi
QL
+
-
y
y
4Be_Cy
a1
a1
∫
Press
Pressure
O [1]
a2
Ctm
Press
a3
Dm
Speed
a4
Dm
Press
+
+
y1
y1
1_Jm
a5
a5
∫
Speed
Speed
∫
Pos
Position
O [1]
speed
O [1]
a6
Cfv
Speed
f
C.Friction
Speed

Simplified Model



Control Goal:

quick and accurate following of the changing target-angle

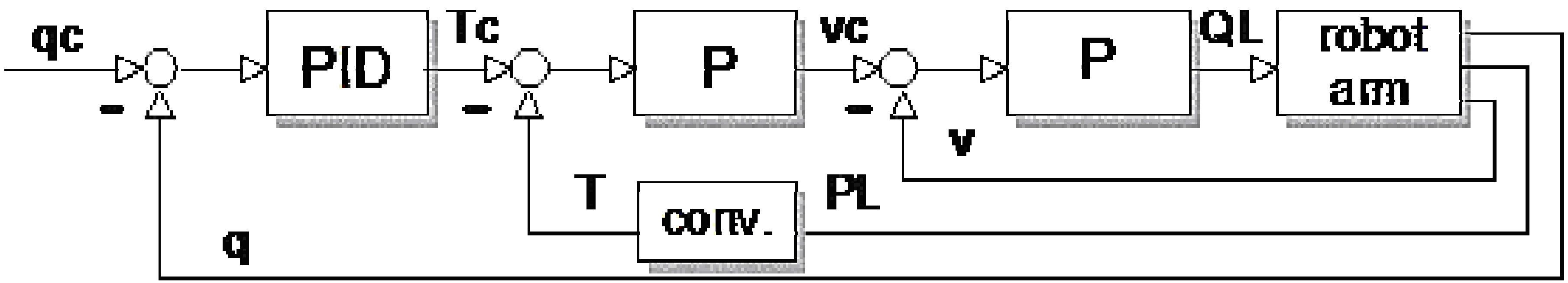
Two operating modes:

(1) **Automatic Mode**: basic control mode; used for joystick remote command or autonomous movements.

(2) **Master-Slave Mode**: the arm (that becomes the slave) follows the movements of a Master arm.

Original Control Structure

For <u>each axis</u> (cascade of 3 control loops):

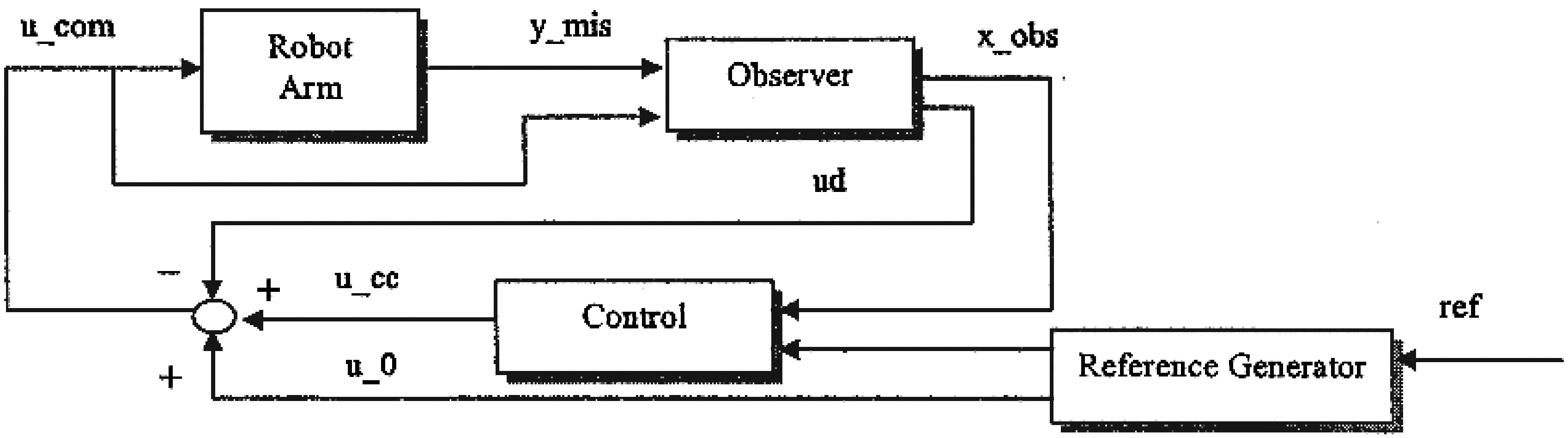


Axis Speed – inner loop

Speed Reference – torque controller

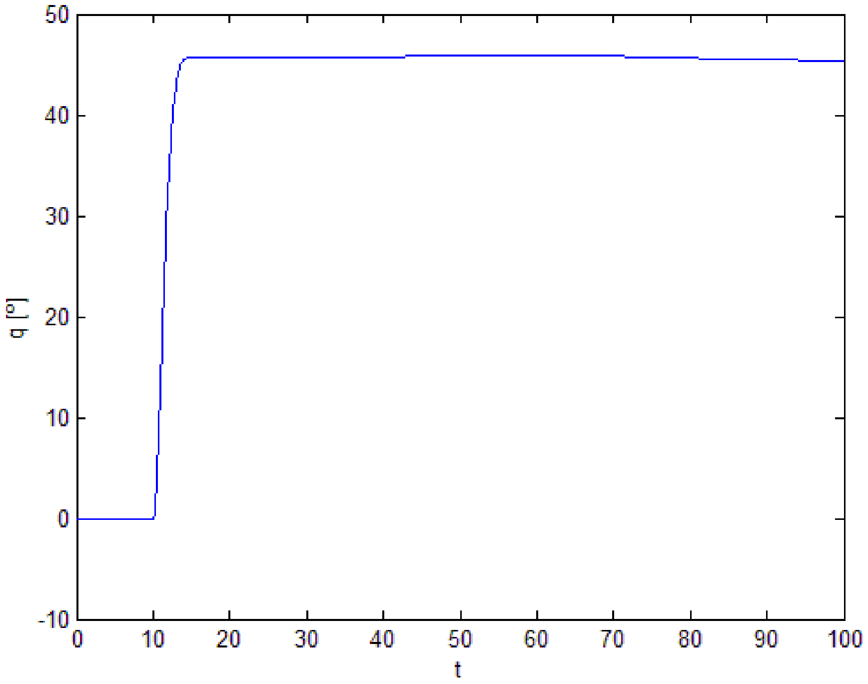
Axis Position – outer loop

Based on the **Automatic Algorithm Generation** (*AAG*) feature:

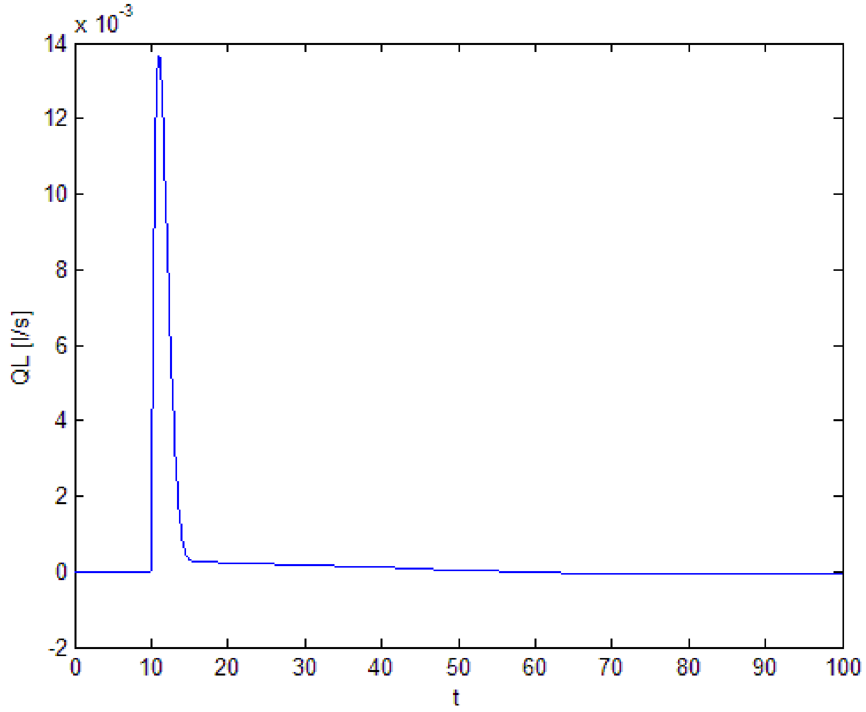


Original Control Structure

Position



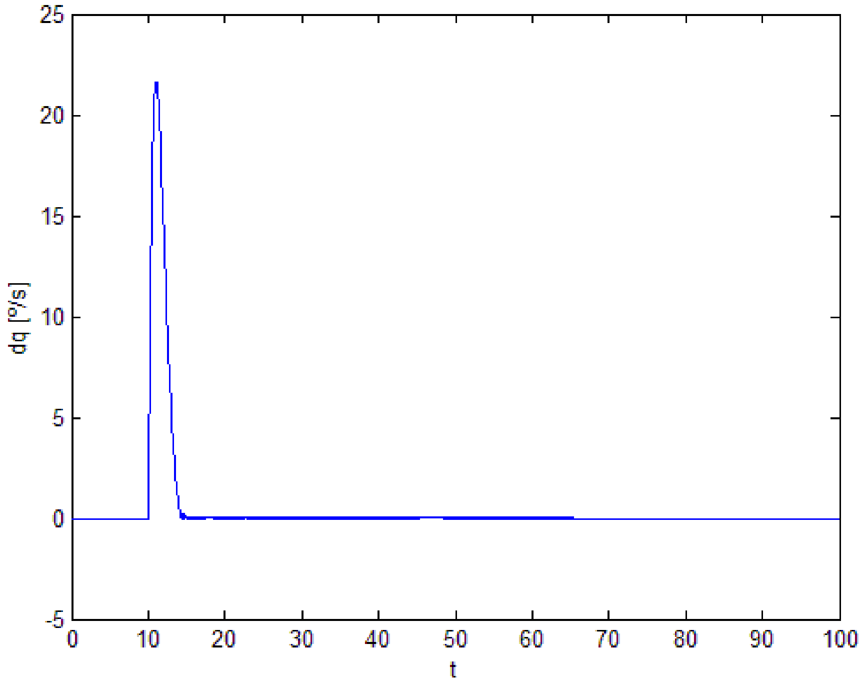
Flow



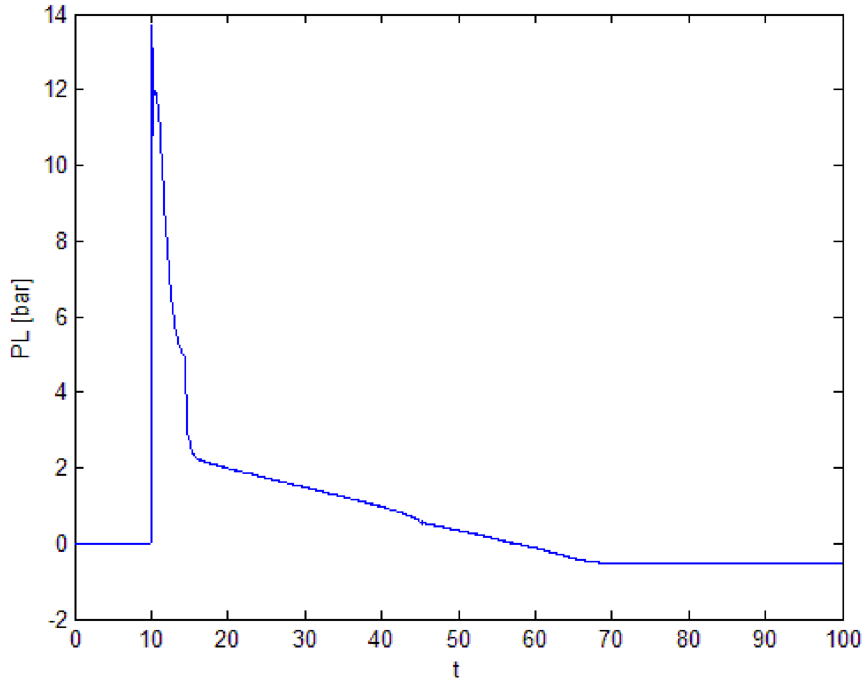
Simulation

Original Control Structure

Speed

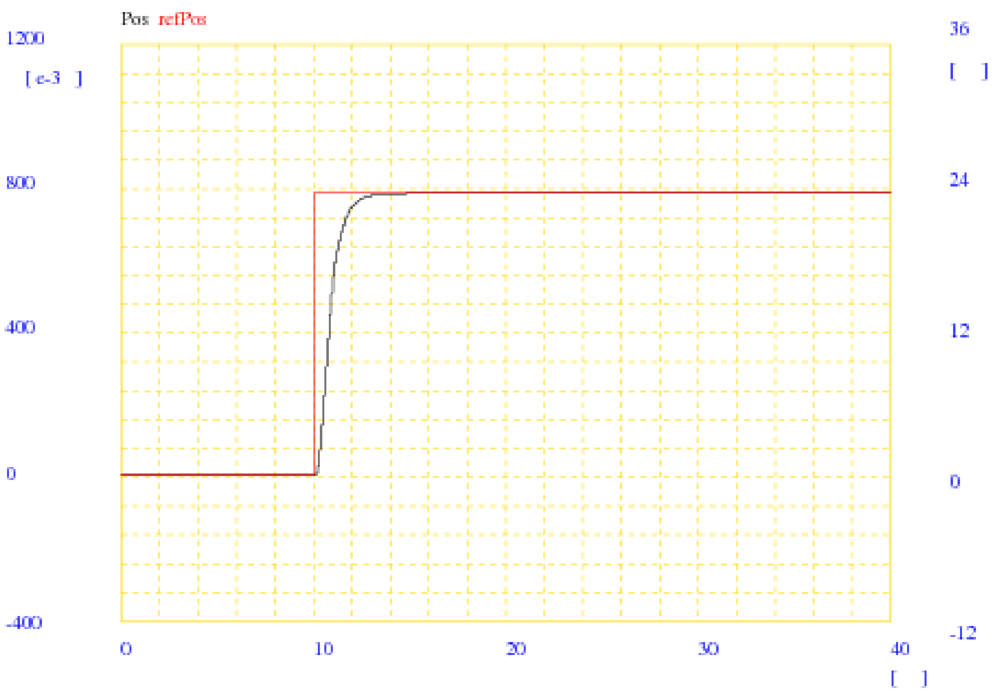


Pressure

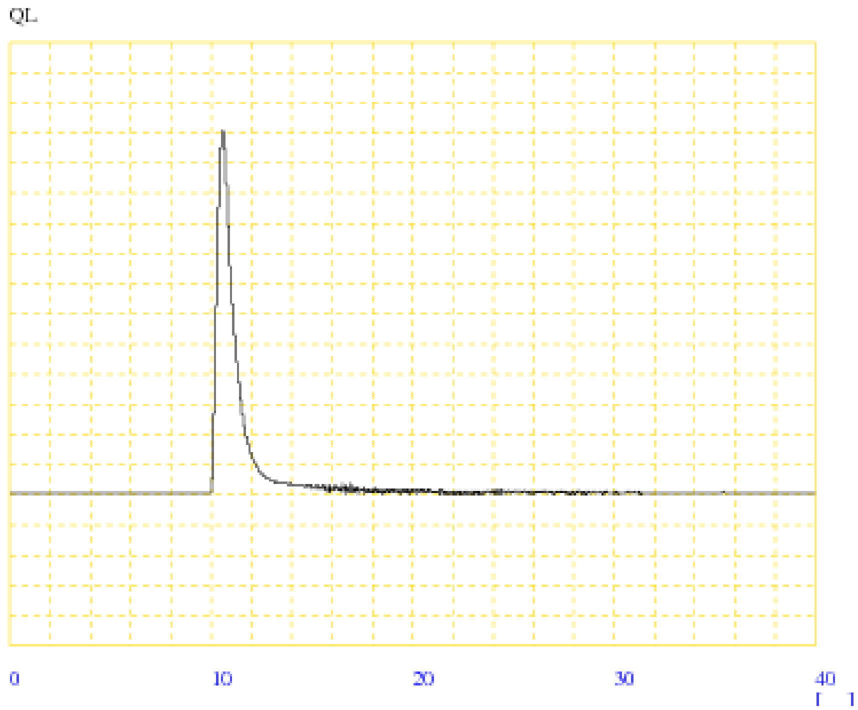


EicasLab Control Structure

Position

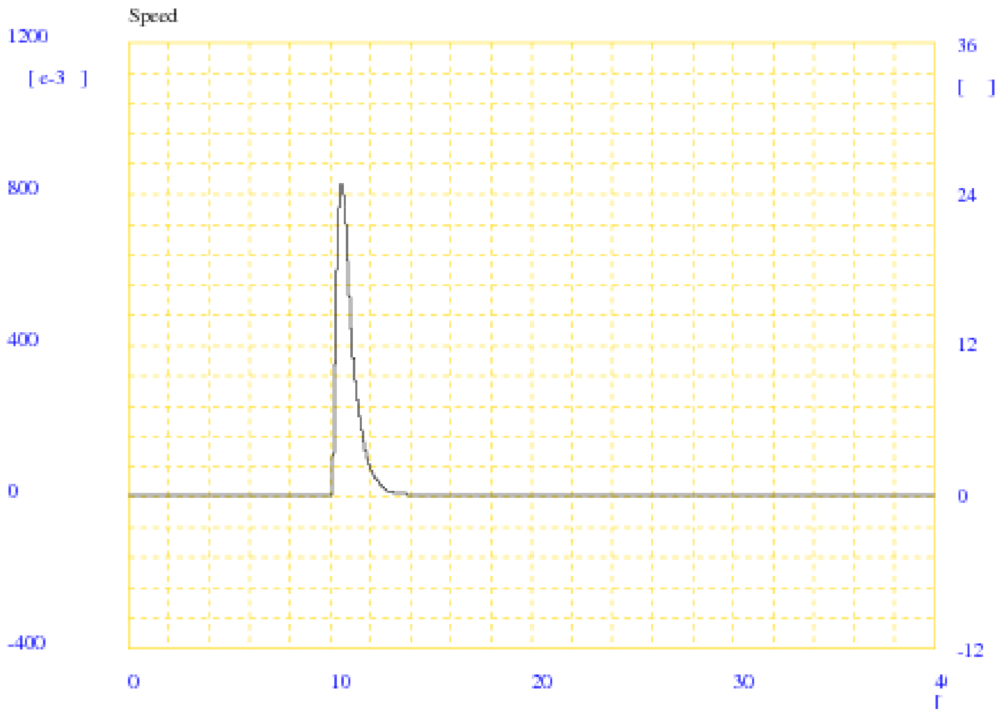


Flow

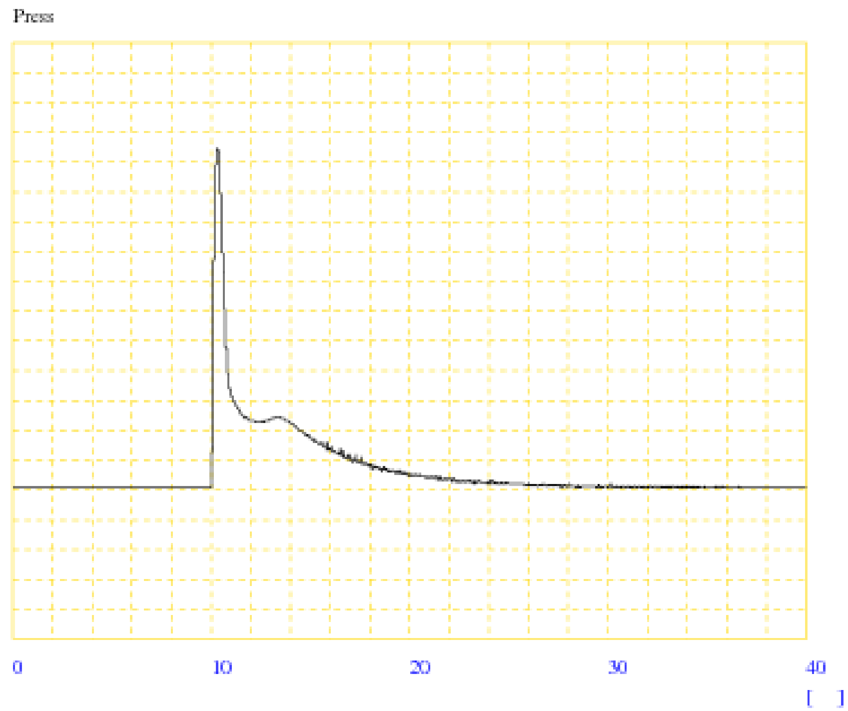


EicasLab Control Structure

Speed



Pressure



Conclusions

Application of Eicas methodology to a robot arm

Comparison between Eicas Methodology and traditional control system

Results reveal:

- sophisticated control techniques in reduced time without specific know-how
- valid alternative to previous control structure