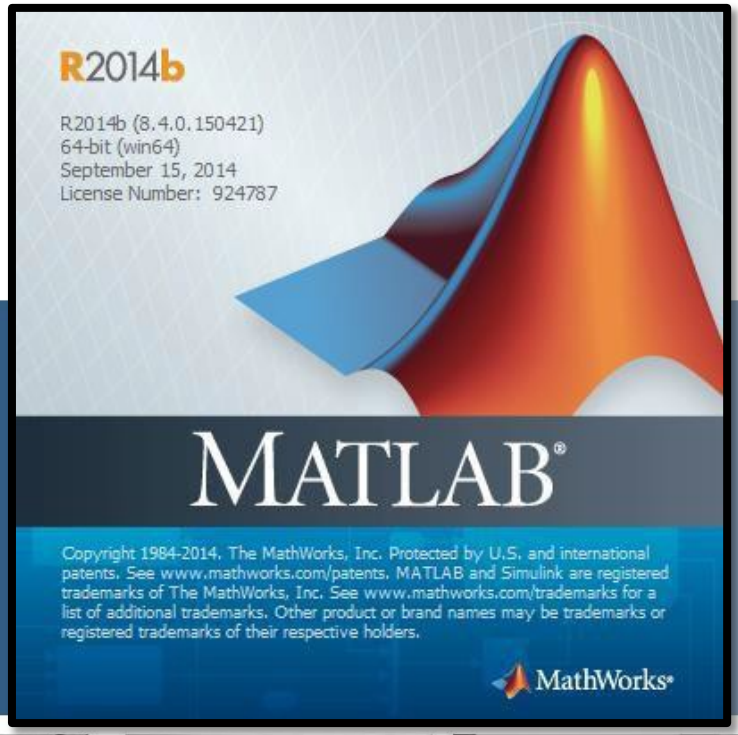
POLITECNICO DI MILANO







Esercitazione 9

Corso di Strumentazione e Controllo di impianti chimici

Prof. Davide Manca

PSE-Lab

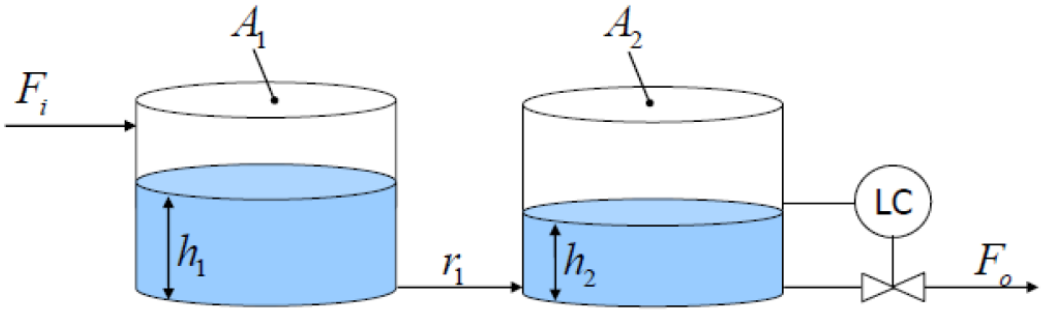
Problema

Esercitazione 9

Dati

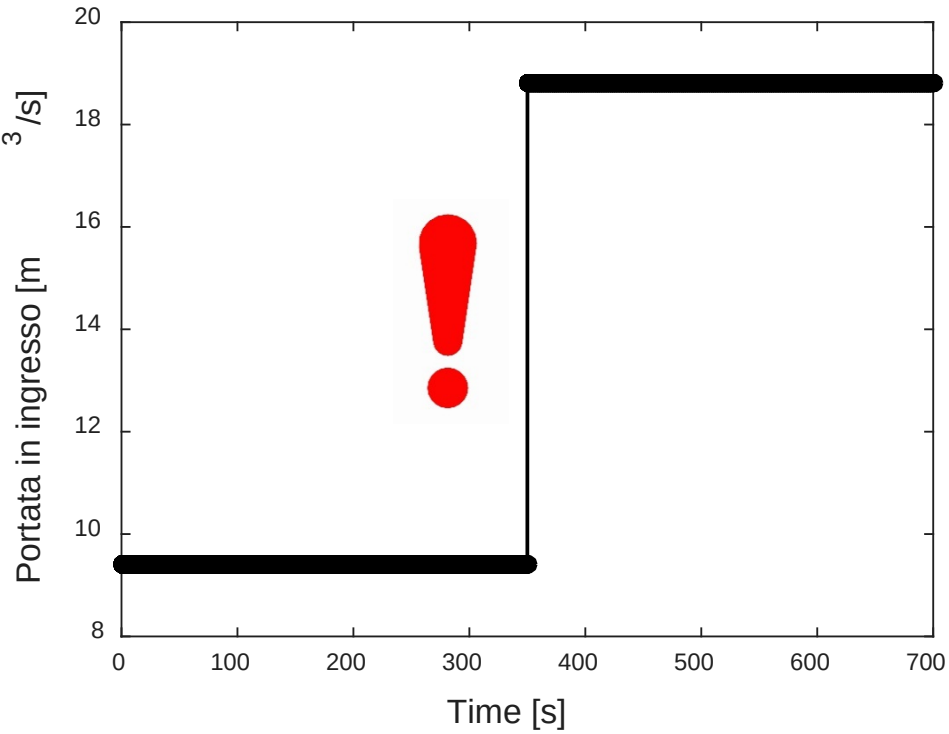
$$F_i = 9.4\frac{m^2}{s} \qquad A_1 = 30\ m^2 \qquad A_2 = 50\ m^2$$

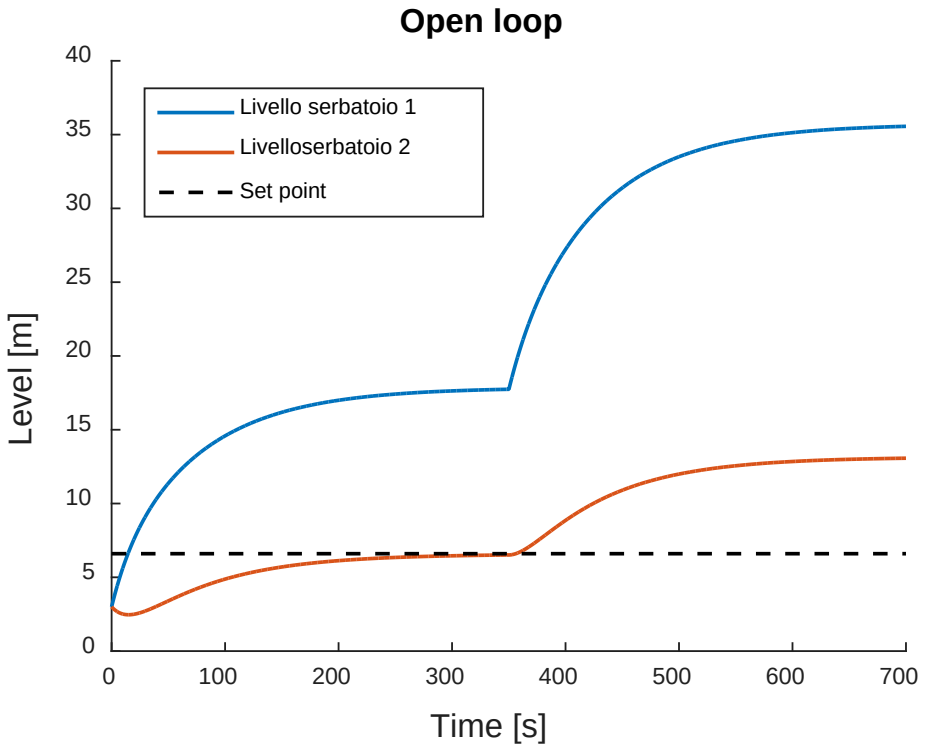
$$R_1 = 1.2\frac{s}{m^2} \qquad h_0 = 3\ m \qquad C_d = 1.43$$



Anello aperto

Come reagisce il sistema al disturbo a gradino (in assenza di controllore)?



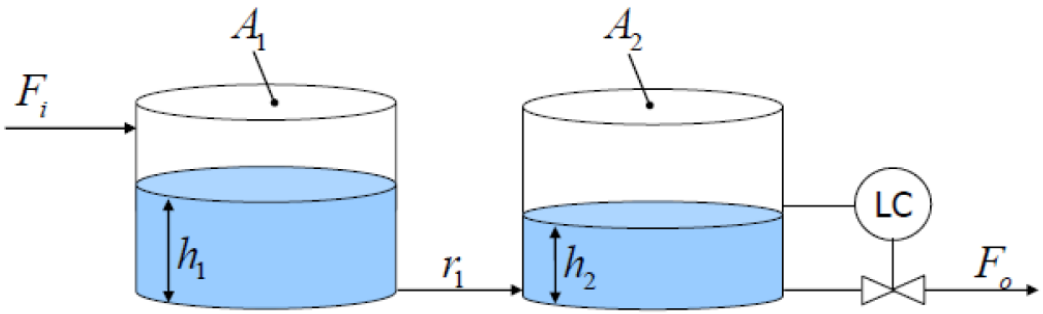


Problema

Caratteristiche del closed-loop:

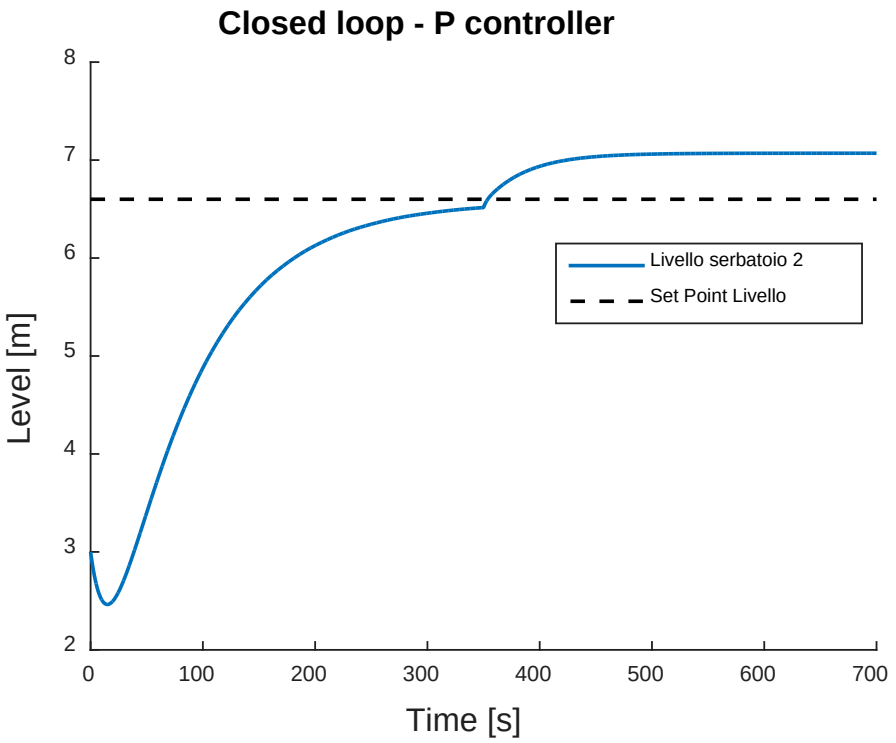
- Variabile Controllata = Livello
- Variabile Manipolata = Portata uscente dal 2° serbatoio

$$y_{set\ point} = 6.6\ m$$



Azione P

Qual è l'effetto del controllore di tipo proporzionale?



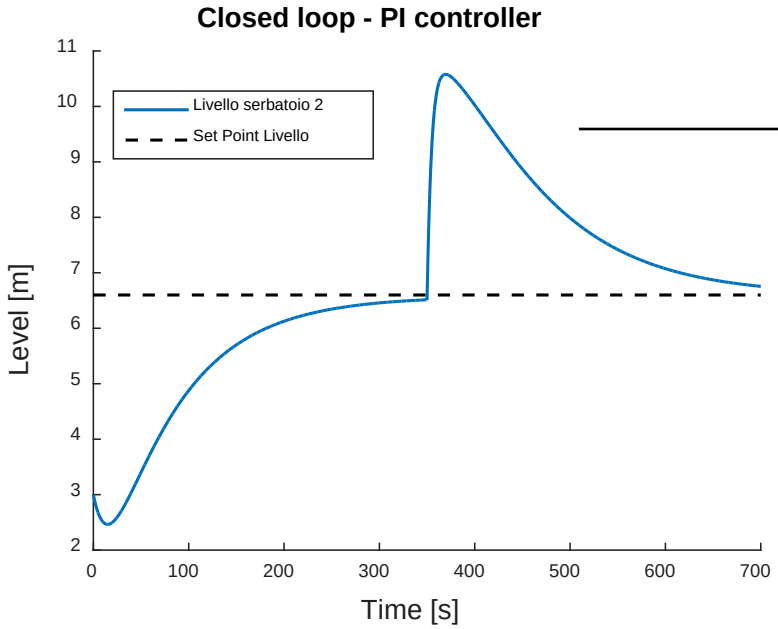
→ **Final offset: ε > 0**

Legge di controllo:

$$c(t) = c_s + k_c \cdot \varepsilon$$

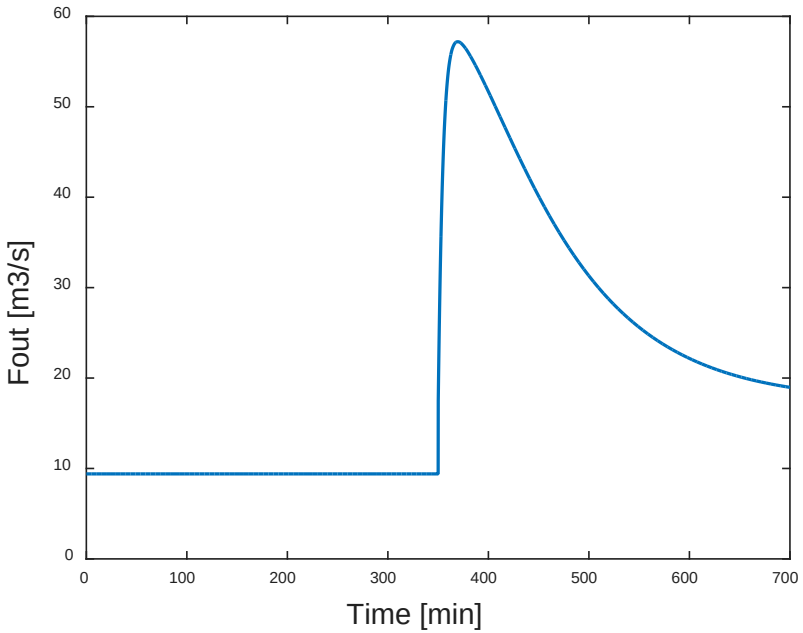
Azione PI

Qual è l'effetto del controllore di tipo proporzionale-integrale?



→ **Presenza di un «overshoot»**

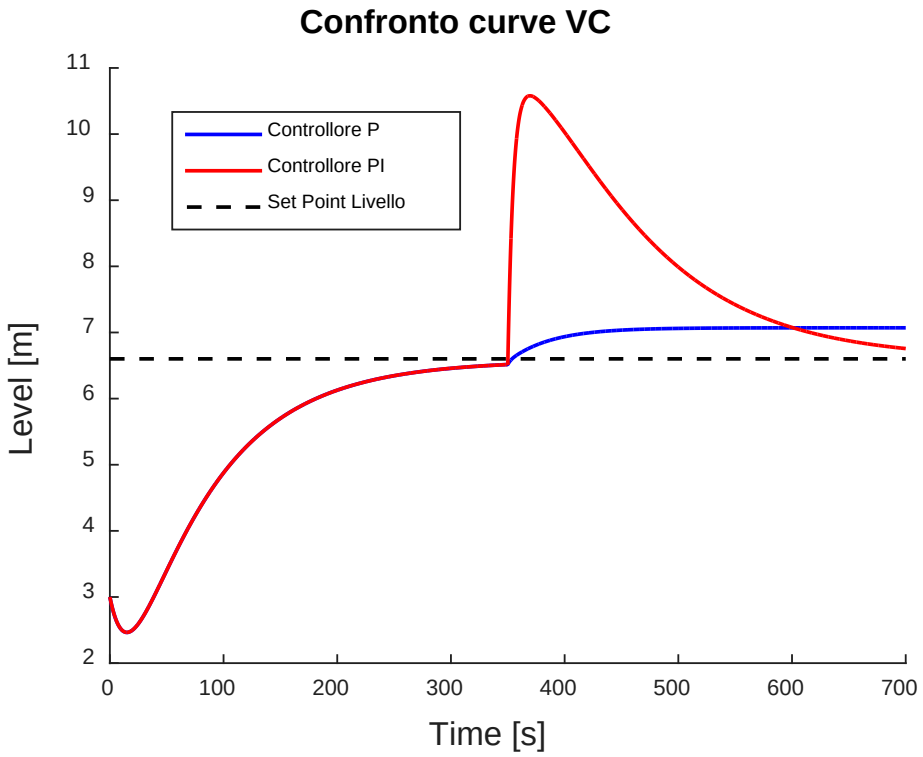
Variabile manipolata



Legge di controllo:

$$c(t) = c_s + k_c \cdot \varepsilon + k_c \cdot \int \varepsilon \, dt$$

Effetto Azione P vs PI



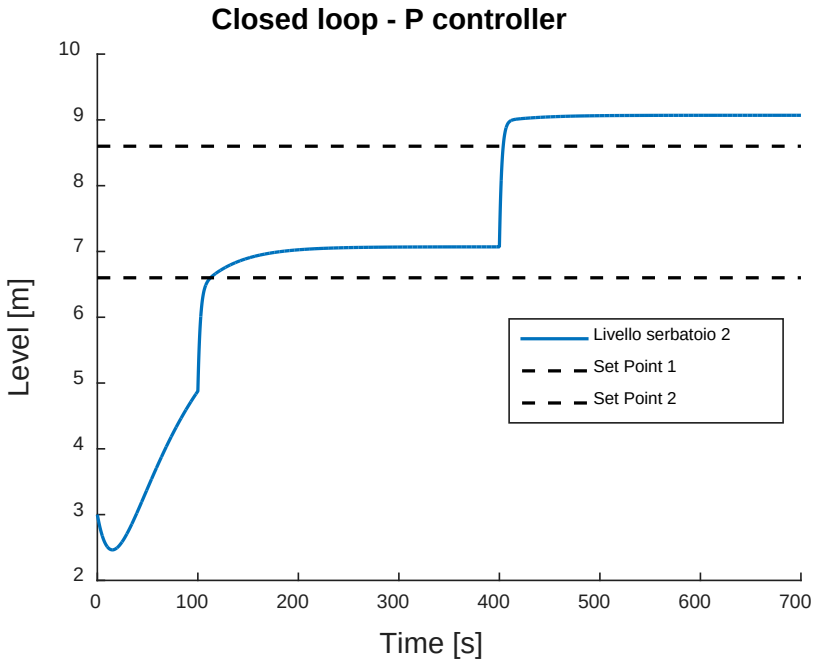
Azione proporzionale:

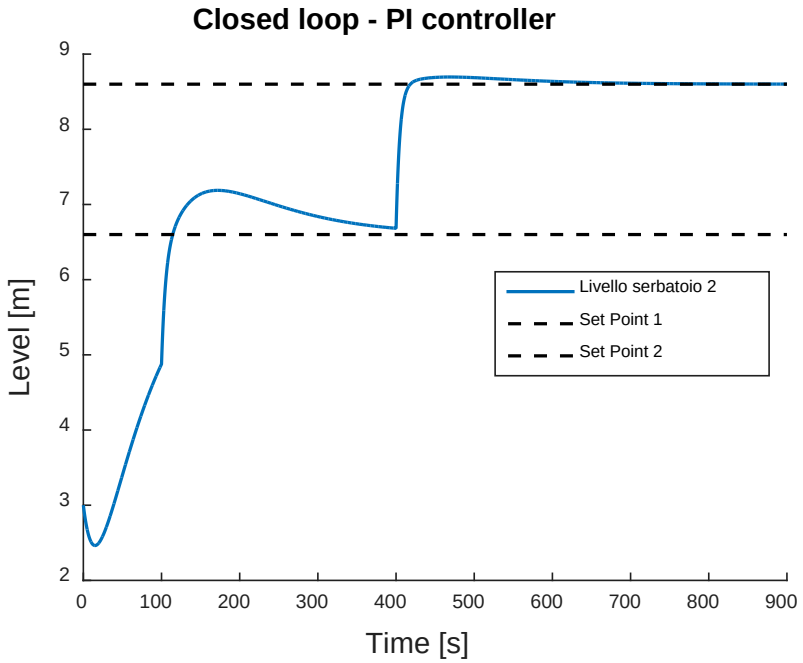
- Garantisce PRONTEZZA della risposta
- Non garantisce PRECISIONE DELLA REGOLAZIONE

Azione proporzionale - integrale:

- Garantisce PRECISIONE DELLA REGOLAZIONE
- All'aumento del rapporto Kc/tau I aumenta la velocità della risposta ma è possibile avere instabilità nel sistema
- L'ordine della risposta è aumentato

Cambio Set point





How to

```
function Ese_9
clc
close all
clear all
global R1 A1 A2 livelloSetPoint Kc tDisturbo coeffScarico h0 tau_
   % Data
% Serbatoio 1
   A1 = 30.; % [m2] area serbatoio 1
   A2 = 50.; % [m2] area serbatoio 2
   R1 = 1.2; % [s/m2] resistenza al flusso -> Fout = (h1-h2)/r
   Fin = 9.4; % [m3/s]
   h0 = 3.; % [m]  livello iniziale nei due serbatoi

% Serbatoio 2
   coeffScarico = 1.43;     %   [m2/s] La legge prevede: Fo =
1.43*h2
   livelloSetPoint = 6.6; % [m]
   tDisturbo = 350.; %[s] tempo al qual introduco il disturbo a
gradino sulla portata IN Fin
```

How to

```
% Comando OPEN LOOP
   tspan = [0:0.1:700];
   [t,L] = ode23s(@ODELivelloSerbatoi,tspan,[h0 h0]);


    for i = 1: length(t)
        LivelloSetPoint(i) = livelloSetPoint;
    end

   figure(1)
   hold on
   title('Open loop','Fontsize',18)
   set(gca,'fontsize',13)
   plot(t,L(:,1),'LineWidth',1.5)
   plot(t,L(:,2),'LineWidth',1.5)
   plot(t,LivelloSetPoint,'k--','LineWidth',1.5)
   xlabel('Time [s]','Fontsize',18)
   ylabel('Level [m]','Fontsize',18)
   legend('Livello serbatoio 1','Livelloserbatoio 2','Set point')
   xlim([0 tspan(length(tspan))])
```

How to

```
   % Grafico portata IN
  indexDisturbo = find(t >=tDisturbo);
for  i = 1:length(tspan)
    if i <= indexDisturbo(1)
        Fin(i) = 9.4;
    else
        Fin(i) = 9.4*2;
    end
 end

figure(5)
title('Disturbo a gradino','Fontsize',18)
plot(tspan,Fin,'Color','k','Marker','o','LineWidth',1.5)
xlabel('Time [s]','Fontsize',18)
ylabel('Portata in ingresso [m^3/s]','Fontsize',18)
xlim([0 700])
set(gca,'fontsize',13)
```

How to

```
% Comando Controllore P
    Kc = 20;
    tspan = [0 :0.1: 700];
    [t1,L1] = ode23s(@ODELivelloSerbatoiControlloP,tspan,[h0 h0]);

    for i = 1: length(t1)
        LivelloSetPoint(i) = livelloSetPoint;
    end

   figure(2)
   hold on
   set(gca,'fontsize',12)
   title('Closed loop - P controller','Fontsize',18)
   plot(t1,L1(:,2),'LineWidth',1.5)
   plot(t1,LivelloSetPoint,'k--','LineWidth',1.5)
   xlabel('Time [s]','Fontsize',18)
   ylabel('Level [m]','Fontsize',18)
   legend('Livello serbatoio 2','Set Point Livello')
  xlim([0 tspan(length(tspan))])
```

How to

```
% Comando Controllore PI
    Kc = 10;
    tau_I = 100;
    tspan = [0 :0.1: 700];
    [t2,L2] =
ode23s(@ODELivelloSerbatoiControlloPI,tspan,[h0 h0 0]);

    for i = 1: length(t1)
        LivelloSetPoint(i) = livelloSetPoint;
    end
       figure(3)
   hold on
   set(gca,'fontsize',12)
   title('Closed loop - PI controller','Fontsize',18)
   plot(t2,L2(:,2),'LineWidth',1.5)
   plot(t2,LivelloSetPoint,'k--','LineWidth',1.5)
   xlabel('Time [s]','Fontsize',18)
   ylabel('Level [m]','Fontsize',18)
  legend('Livello serbatoio 2','Set Point Livello')
   xlim([0 tspan(length(tspan))])
```

How to

```
  % Grafico PORTATA Fout

  indexDisturbo = find(t2 >= tDisturbo);
     for i = 1: length(t2)
         epsi(i) = + L2(i,2) - livelloSetPoint;
         if i <= indexDisturbo(1)
         Fout(i) = 9.4;
         else
          Fout(i) = 9.4 + Kc * epsi(i) +
Kc / tau_I *L2(length(L2(:,3)),3);
          end
     end

  figure(10)
  plot(t2,Fout,'LineWidth',1.5)
  xlabel('Time [min]','Fontsize',18)
  ylabel('Fout [m3/s]','Fontsize',18)

end % chiudo la function Ese_9
```

How to

```
function dy = ODELivelloSerbatoi(t,y)

  global R1 A1 A2 livelloSetPoint Kc tDisturbo
coeffScarico
% %
if t < tDisturbo
    Fin = 9.4;
else
    Fin = 2*9.4;
end

% Fin = 9.4;
% [y(1)] = livello serbatoio 1
% [y(2)] = livello serbatoio 2

dy(1,:) = 1/A1*(Fin - (y(1)-y(2))/R1);
dy(2,:) = 1/A2*((y(1)-y(2))/R1 - coeffScarico*y(2));

end
```

How to

```
function dy = ODELivelloSerbatoiControlloP(t,y)

  global R1 A1 A2 livelloSetPoint Kc tDisturbo
coeffScarico h0
epsi =  y(2) - livelloSetPoint ;

if t < tDisturbo
    Fin = 9.4;
    Fout = coeffScarico*y(2);
else
    Fin = 2*9.4;
    Fin_ss = 9.4;
      % VM = Fout
Fout = Fin_ss + Kc*epsi;
end
% [y(1)] = livello serbatoio 1
% [y(2)] = livello serbatoio 2
dy(1,:) = 1/A1*( Fin - (y(1)-y(2))/R1);
dy(2,:) = 1/A2*((y(1)-y(2))/R1 - Fout);
end
```

How to

```
function dy = ODELivelloSerbatoiControlloPI(t,y)

  global R1 A1 A2 livelloSetPoint Kc tDisturbo
coeffScarico h0 tau_I
% [y(1)] = livello serbatoio 1
% [y(2)] = livello serbatoio 2
% [y(3)] = Integrale di epsi in dt
epsi =  y(2) - livelloSetPoint ;
if t < tDisturbo
    Fin = 9.4;
    Fout = coeffScarico*y(2);
else
    Fin = 2*9.4;
      % VM = Fout ( portata uscente dal secondo serbatoio)
  Fout = 9.4 + Kc*epsi + Kc/tau_I *y(3);
end
dy(1,:) = 1/A1*( Fin - (y(1)-y(2))/R1);
dy(2,:) = 1/A2*((y(1)-y(2))/R1 - Fout);
dy(3,:) = epsi;
end
```