Modelarea si identificarea unei instalatii hidraulice cu doua rezervoare

Seminar stiintific
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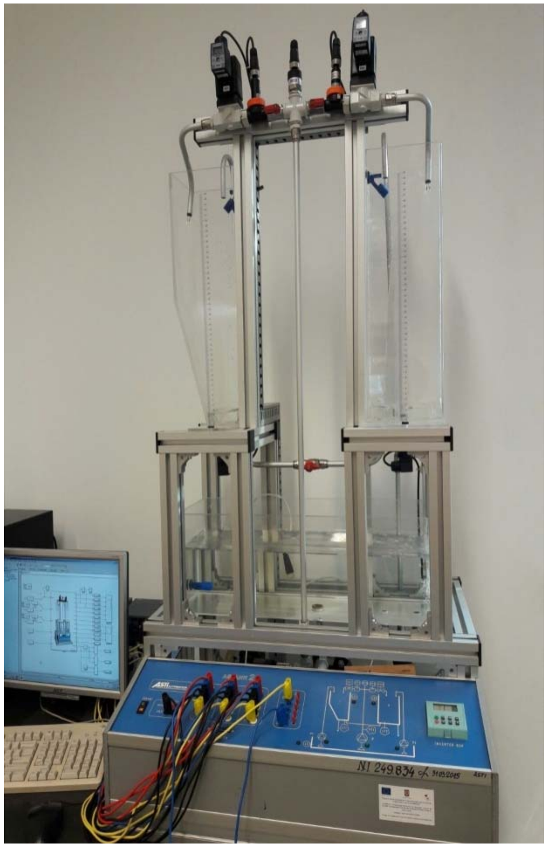


1. Motivatie

- Procesele fluidice - intalnite in diferite domenii ale industriei (energie, petro-chimie, tratarea apei) sau in agricultura;
- Sunt constituite din rezervoare multiple interactive - procese multivariable cu dinamica neliniara;
- In literatura de specialitate :

  - sunt prezentate instalatii cu 2, 3, 4 rezervoare (clasic)

  - diferite forme geometrice (rectangulare, conice, sferice) -> modele nelinare

  - aplicarea variatelor strategii de control pentru nivelul de lichid din rezervoare (PI, PID, bazate pe logica fuzzy, MPC)

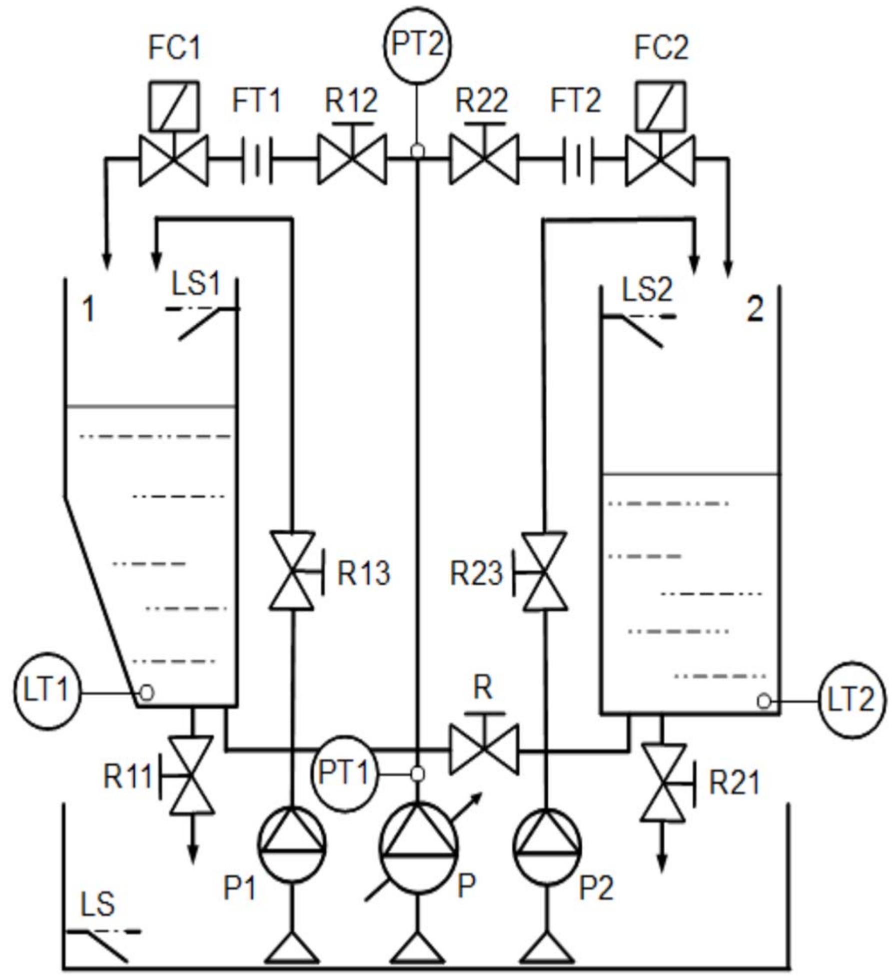
  Observatie ! Modelele prezentate sunt modele analitice (clasice)

- *Propuneri* : modele analitic; analitic si experimental; experimental

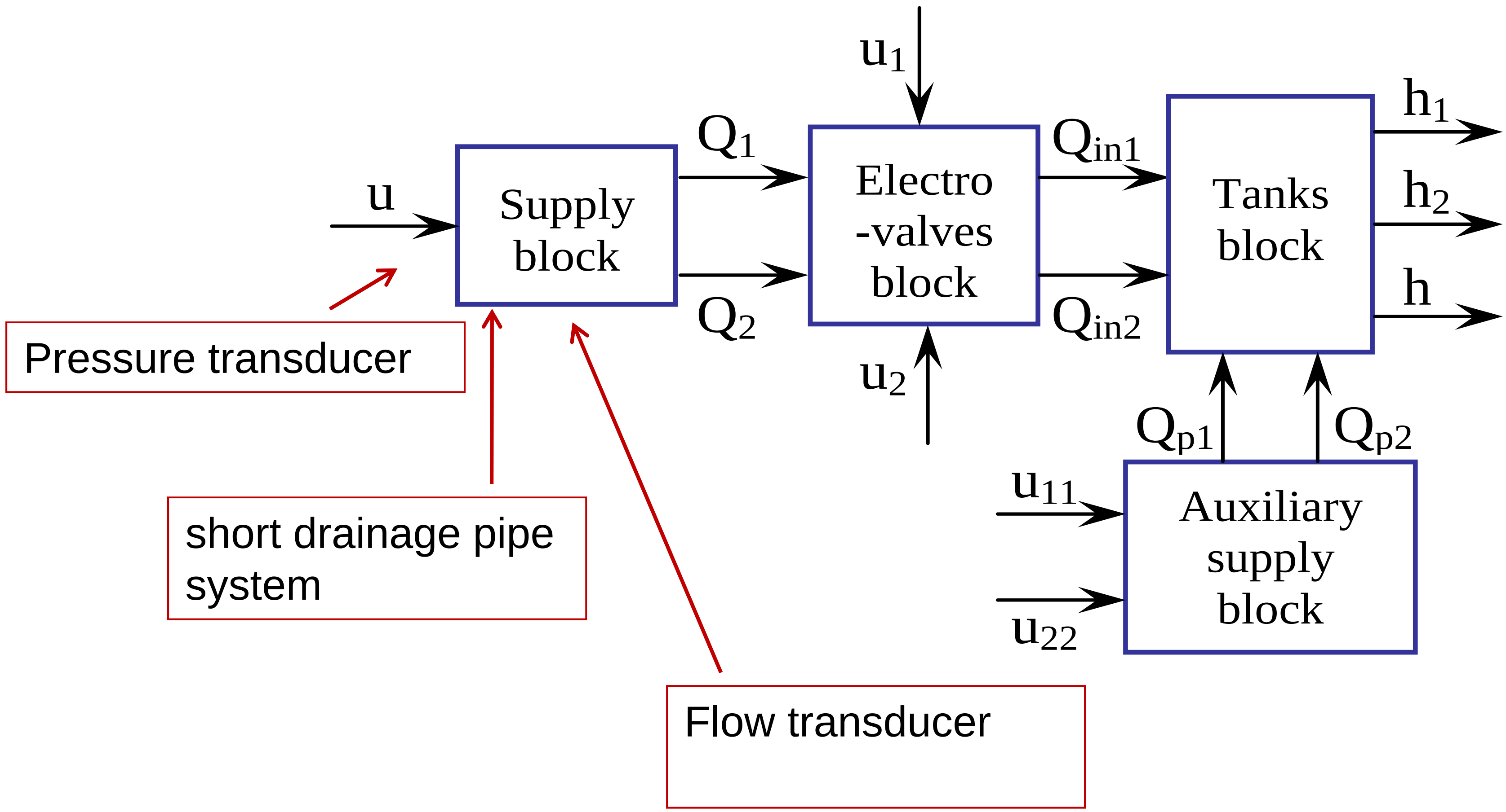
2. Prezentarea instalatiei ASTANK2

Caracteristici :

- Versatilitate
- Forma geometrica neregulata pentru primul rezervor - prisma
- Proces multivariabil
- **Marimi de intrare:**
  - tensiunea de alimentare a pompei principale P - **u**;
  - Tensiunile aplicate pe fiecare electro-valva FC1, FC2 – $\mathbf{u_1}$, $\mathbf{u_2}$
  - Setarea ON/OFF a pompelor auxiliare ($\mathbf{u_{11}}$, $\mathbf{u_{22}}$)
- **Marimi de iesire** : nivelurile de lichid din rezervoarele principale ($\mathbf{h_1}$, $\mathbf{h_2}$)

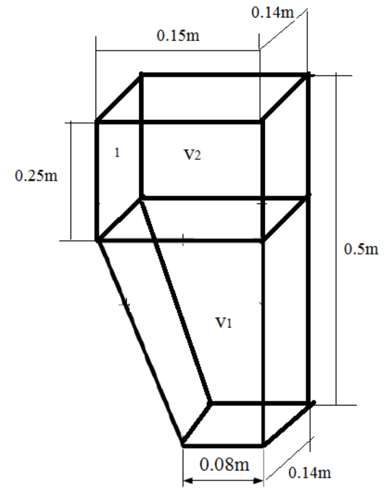


3. Modelul analitic (1)



3. Modelul analitic (2)

- Rezervor prismatic:



$$V_1(h_1)=\begin{cases} L\cdot l\cdot h_1+\dfrac{h_1^2\cdot l\cdot\tan\theta}{2} & ,h_1\le H\\ h_1\cdot l\cdot(L+H\cdot\tan\theta)-\dfrac{H^2\cdot l\cdot\tan\theta}{2} & ,h_1>H\end{cases}$$

- Modelul analitic :

$$\begin{cases} \left[L\cdot l+l\cdot\tan\theta\cdot h_1(t)\right]\dfrac{dh_1(t)}{dt}=Q_{in1}(t)-a_1\sqrt{2\left[gh_1(t)\left[1+\dfrac{h_1(t)}{4L}\sin(2\theta)\right]\right]}; & ,h_1\le H\\ l\cdot(L+H\cdot\tan\theta)\cdot\dfrac{dh_1(t)}{dt}=Q_{in1}(t)-a_1\sqrt{2gh_1(t)\left[1+\dfrac{H}{2L}\sin(2\theta)\right]-g\dfrac{H^2}{2L}\sin(2\theta)} & ,h_1>H\end{cases}$$

3. Modelul analitic (3)

- Modelul analitic al rezervorului paralelipipedic:

$$A_2 \frac{dh_2(t)}{dt} = Q_{in2}(t) - a_2\sqrt{2gh_2(t)}$$

- Modelul analitic al rezervorului acumulator:

$$\begin{cases} A_T \dfrac{dh(t)}{dt} = a_1\sqrt{2\left[gh_1(t)\left[1+\dfrac{h_1(t)}{4L}\sin(2\theta)\right]\right]} + a_2\sqrt{2gh_2(t)} - Q(t); & ,h_1 \le H \\ A_T \dfrac{dh(t)}{dt} = a_1\sqrt{2gh_1(t)\left[1+\dfrac{H}{2L}\sin(2\theta)\right] - g\dfrac{H^2}{2L}\sin(2\theta)} + a_2\sqrt{2gh_2(t)} - Q(t) & ,h_1 > H \end{cases}$$

Debitul pe conducta de comunicare:

$$Q_c = a_c \operatorname{sign}\left(P(h_1) - \rho g h_2\right)\sqrt{\frac{2\left(P(h_1) - \rho g h_2\right)}{\rho}}$$

3. Modelul analitic al rezervoarelor (4)

$$h_1 \le H$$

$$\left[L\cdot l + l\cdot h_1(t)\cdot \tan\theta\right]\frac{dh_1(t)}{dt} = Q_{in1}(t) + Q_{p1}(t) -$$

$$- a_1\sqrt{2\left[gh_1(t)\left[1+\frac{h_1(t)}{4\cdot L}\sin(2\theta)\right]\right]} -$$

$$- a_c \operatorname{sign}\left(h_1(t) - h_2(t) + \frac{h_1^2(t)}{4L}\sin(2\theta)\right)\times$$

$$\times\sqrt{2g\left(h_1(t)-h_2(t)\right)+\frac{\rho g h_1^2(t)}{4L}\sin(2\theta)};$$

$$A_2\frac{dh_2(t)}{dt} = Q_{in2}(t) + Q_{p1}(t) - a_2\cdot\sqrt{2gh_2(t)} +$$

$$+ a_c \operatorname{sign}\left(h_1(t) - h_2(t) + \frac{h_1^2(t)}{4L}\sin(2\theta)\right)\times$$

$$\times\sqrt{2g\left(h_1(t)-h_2(t)\right)+\frac{\rho g h_1^2(t)}{4L}\sin(2\theta)};$$

$$A_T\frac{dh(t)}{dt} = a_1\sqrt{2\left[gh_1(t)\left[1+\frac{h_1(t)}{4L}\sin(2\theta)\right]\right]} +$$

$$+ a_2\sqrt{2gh_2(t)} - Q(t) - Q_{p1}(t) - Q_{p2}(t).$$

$$h_1 > H$$

$$l\left(L + H\cdot\tan\theta\right)\frac{dh_1(t)}{dt} = Q_{in1}(t) + Q_{p1}(t) -$$

$$- a_1\sqrt{2gh_1(t)\left[1+\frac{H}{2L}\sin(2\theta)\right] - g\frac{H^2}{2L}\sin(2\theta)} -$$

$$- a_c \operatorname{sign}\left(h_1(t) - h_2(t) + \frac{h_1(t)H}{2L}\sin(2\theta) - \frac{H^2}{4L}\sin(2\theta)\right)\times$$

$$\times\sqrt{2g\left[h_1(t)-h_2(t)+\frac{h_1(t)H}{2L}\sin(2\theta)-\frac{H^2}{4L}\sin(2\theta)\right]}$$

$$A_2\frac{dh_2(t)}{dt} = Q_{in2}(t) + Q_{p1}(t) - a_2\sqrt{2gh_2(t)} +$$

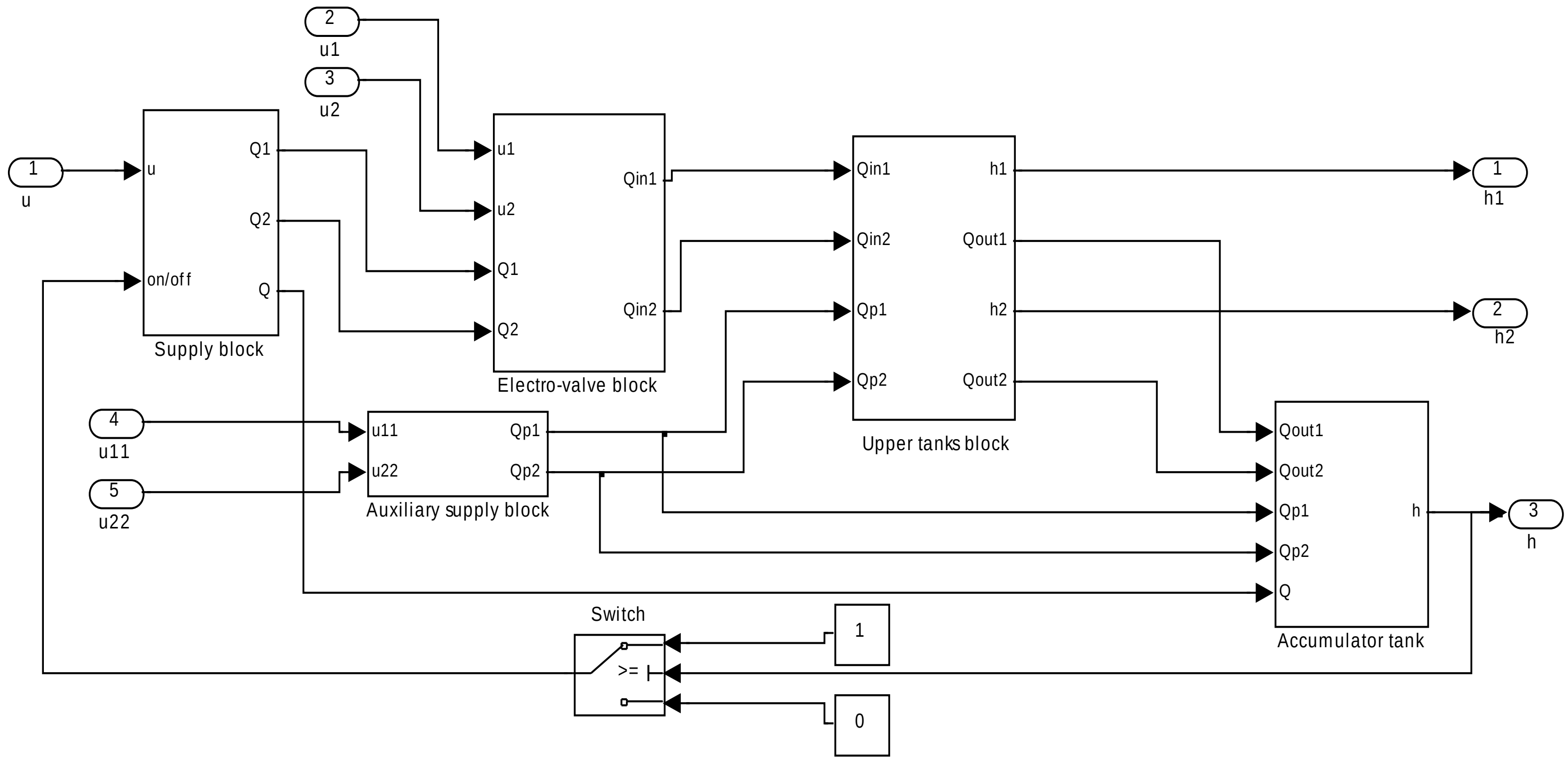
$$+ a_c \operatorname{sign}\left(h_1(t) - h_2(t) + \frac{h_1(t)H}{2L}\sin(2\theta) - \frac{H^2}{4L}\sin(2\theta)\right)\times$$

$$\times\sqrt{2g\left[h_1(t)-h_2(t)+\frac{h_1(t)H}{2L}\sin(2\theta)-\frac{H^2}{4L}\sin(2\theta)\right]}$$

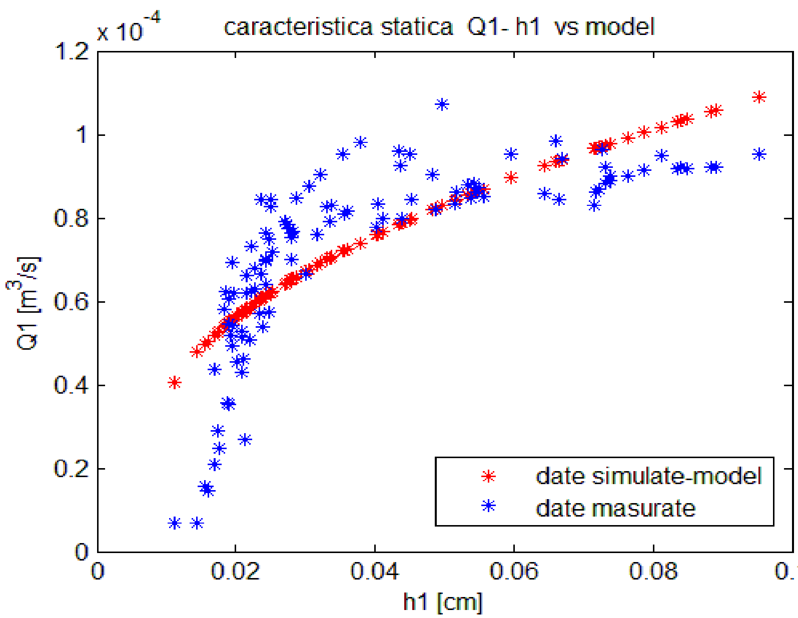
$$A_T\frac{dh(t)}{dt} = a_1\sqrt{2gh_1(t)\left[1+\frac{H}{2L}\sin(2\theta)\right] - g\frac{H^2}{2L}\sin(2\theta)} +$$

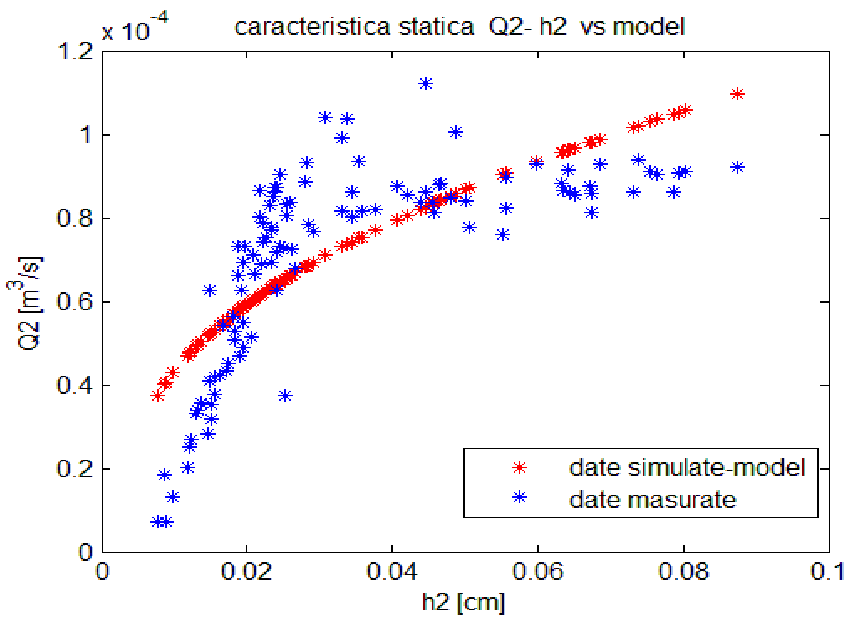
$$+ a_2\sqrt{2gh_2(t)} - Q(t) - Q_{p1}(t) - Q_{p2}(t)$$

3. Modelul analitic (5) ASTANK2 – schema bloc in Simulink



3. Modelul analitic (6)





Dificultati & discutii:

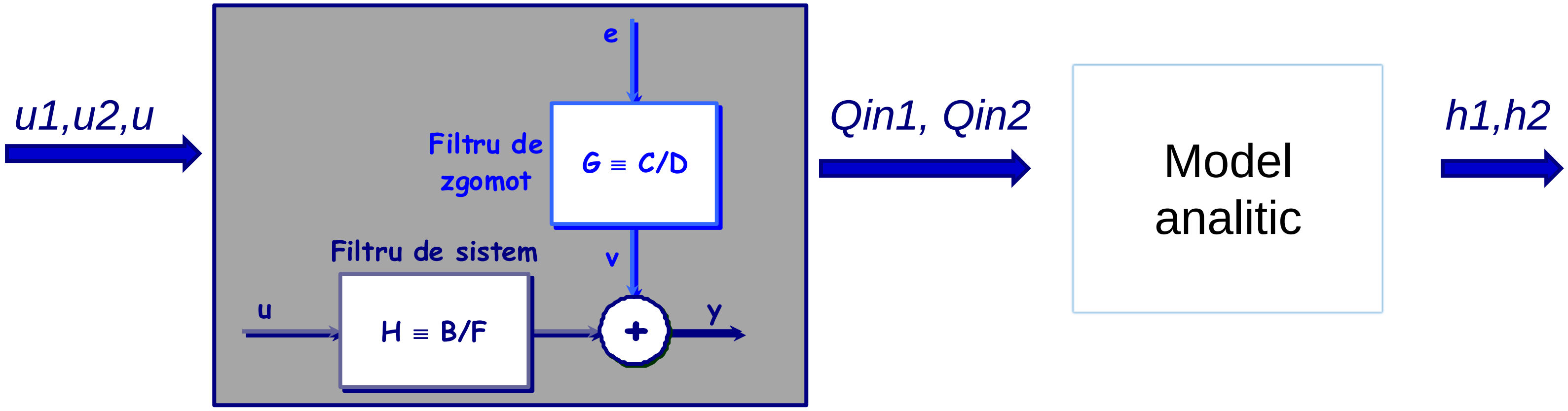
- valorile coeficientilor de curgere dependente de configuratia rezervoarelor (aplicarea LSM)
- determinarea precisa a coeficientilor de curgere a1, a2 , ac in configuratia completa -> necesitatea adaugarii unor senzori de debit la iesirea rezervoarelor
- decalibrarea senzorilor in timpul functionarii instalatiei
- s-a analizat fenomenul de histerezis - > neglijabil

4. Extinderea modelului analitic

- pastrarea modelul analitic al rezervoarelor
- **identificarea** modelelor conductelor de alimentare a rezervoarelor pentru combinatii 0<=u1<=10V , 0<=u2<=10V

  tensiunea u - generare semnal SPA

$\Rightarrow$ *Harta (matrice) de modele => interpolarea modelelor (pentru orice valoare u1 , u2)*



Box-Jenkins [nb,nc,nd,nf] :

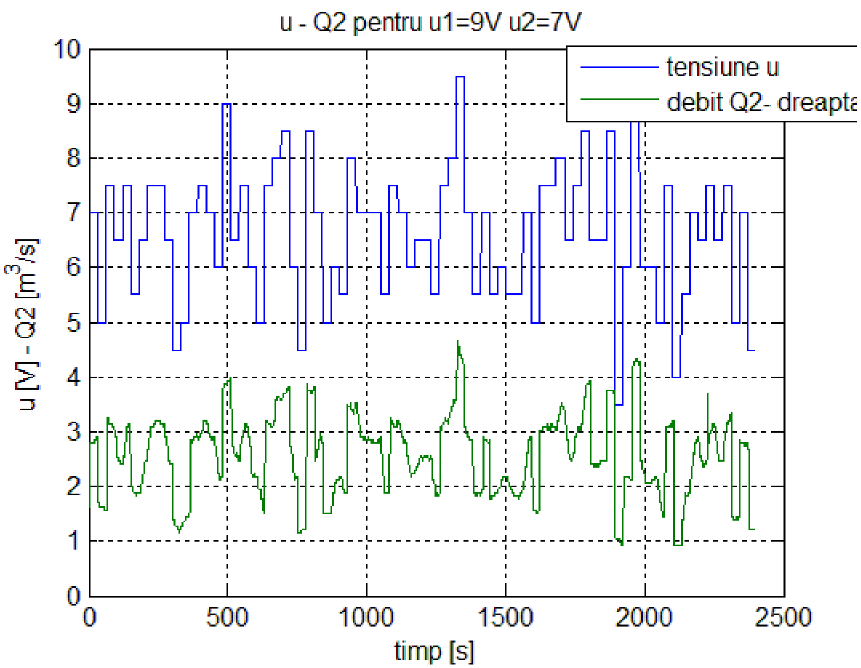
$$\begin{cases} y[n] = \dfrac{B(q^{-1})}{F(q^{-1})}u[n] + \dfrac{C(q^{-1})}{D(q^{-1})}e[n] \\ E\{e[n]e[m]\} = \lambda^2\delta_0[n-m] \end{cases}$$

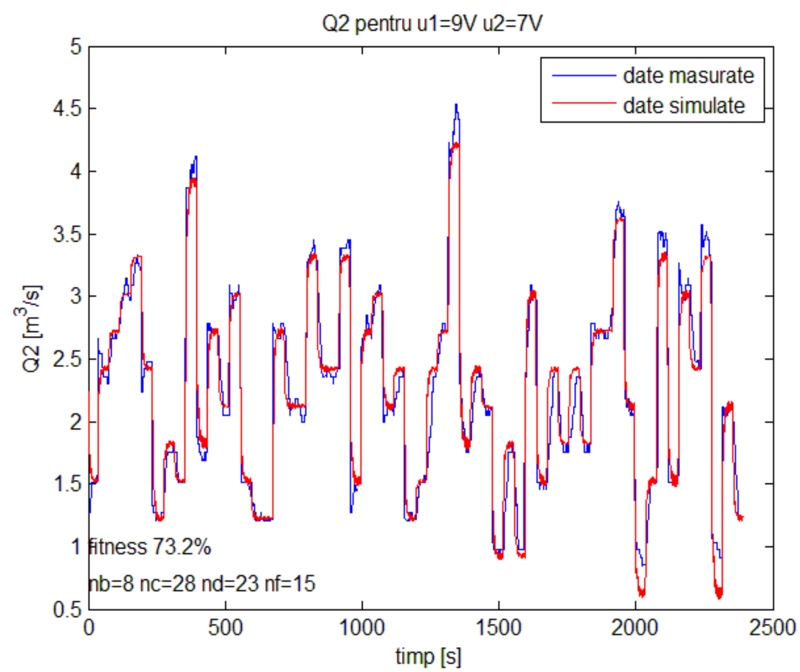
$$\begin{cases} B(q^{-1}) = \quad (b_1 q^{-1} + \cdots + b_{nb} q^{-nb})q^{1-nk} \\ C(q^{-1}) = 1 + c_1 q^{-1} + \cdots + c_{nc} q^{-nc} \\ D(q^{-1}) = 1 + d_1 q^{-1} + \cdots + d_{nd} q^{-nd} \\ F(q^{-1}) = 1 + f_1 q^{-1} + \cdots + f_{nf} q^{-nf} \end{cases}$$

4. Extinderea modelului analitic (2) – Rezultate simulare

Alegerea indicilor structurali optimali : [nb,nc,nd,nf] (1:50) - Metoda empirica (Monte Carlo)

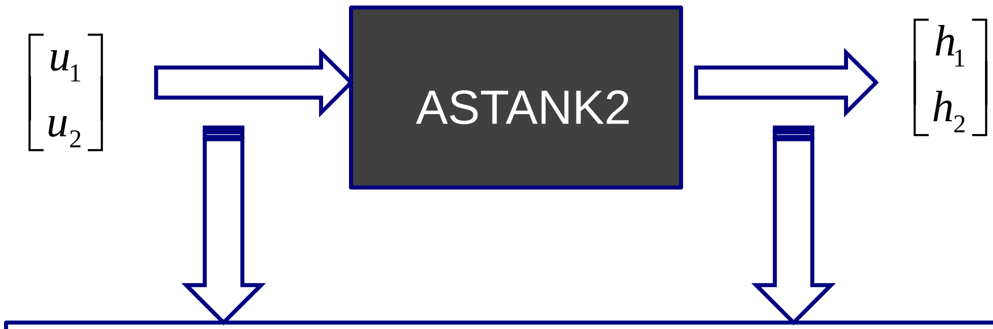
$$\mathbf{E}_N[n\theta] \overset{def}{=} 100\left(1-\sqrt{\frac{\sum_{n=1}^{N}\left|\varepsilon[n,\hat{\boldsymbol{\theta}}_N]\right|^2}{\sum_{n=1}^{N}\left|y[n]-\frac{1}{N}\sum_{n=1}^{N}y[n]\right|^2}}\right)$$





5. Modelul experimental (1)

- **Obiectiv** : controlul nivelului de lichid din rezervoare
- Identificare **multimodel** pe o plaja larga de puncte de functionare, pentru fiecare tensiune u   => PSF (u,u1,u2)



$$\begin{cases} y_1[n] = \dfrac{B_{11}(q^{-1})}{F_{11}(q^{-1})}u_1[n] + \dfrac{B_{21}(q^{-1})}{F_{21}(q^{-1})}u_2[n] + \dfrac{C_1(q^{-1})}{D_1(q^{-1})}e_1[n] \\ y_2[n] = \dfrac{B_{12}(q^{-1})}{F_{12}(q^{-1})}u_1[n] + \dfrac{B_{22}(q^{-1})}{F_{22}(q^{-1})}u_2[n] + \dfrac{C_2(q^{-1})}{D_2(q^{-1})}e_2[n] \end{cases}$$

=> Interpolare modele pentru tensiuni intermediare

5. Modelul experimental (3) – experiment econometric

Generarea marimilor de intrare :

- u1 si u2 – generare SPA => *restrictie* : limitarea salturilor de tensiune la 3V

  variatie nu mai mica de 0.5V
- combinatii de valori acoperitoare pentru intreaga gama de tensiuni ale electro-valvelor
- validarea – inversarea semnalelor de intrare

Dificultati:

- zona de functionare initiala – rezervoare goale =>

  - sub 4 cm - date masurate afectate de zgomot (turbioane)

  - Ts=0.5 s - date masurate perturbate

Remediere:

- alegerea PSF in jurul valorii de 12 cm pentru evitarea turbulentelor care efecteaza senzorii
- Ts=2s

5. Modelul experimental (2) – Algoritm de identificare

$$y[n] = \frac{B_1(q^{-1})}{F_1(q^{-1})} u_1[n] + \frac{B_2(q^{-1})}{F_2(q^{-1})} u_2[n] + \frac{C\ (q^{-1})}{D\ (q^{-1})} e[n]$$

Problema: determinarea indicilor structurali optimali (nb,nf <=30, nc,nd<=100)

x_util= [nb1,nf1,nb2,nf2,nc,nd]

1. Generare aleatoare + combinatii posibile => fitness
2. Algoritm de ascensiune montana cu initializarea de la pasul 2 => Model util M1
3. In vederea estimarii zgomotului
   3.1. C=1, D=1 =>

$$y\_u[n] = \frac{B_1^1(q^{-1})}{F_1^1(q^{-1})} u_1[n] + \frac{B_2^1(q^{-1})}{F_2^1(q^{-1})} u_2[n] + e[n]$$

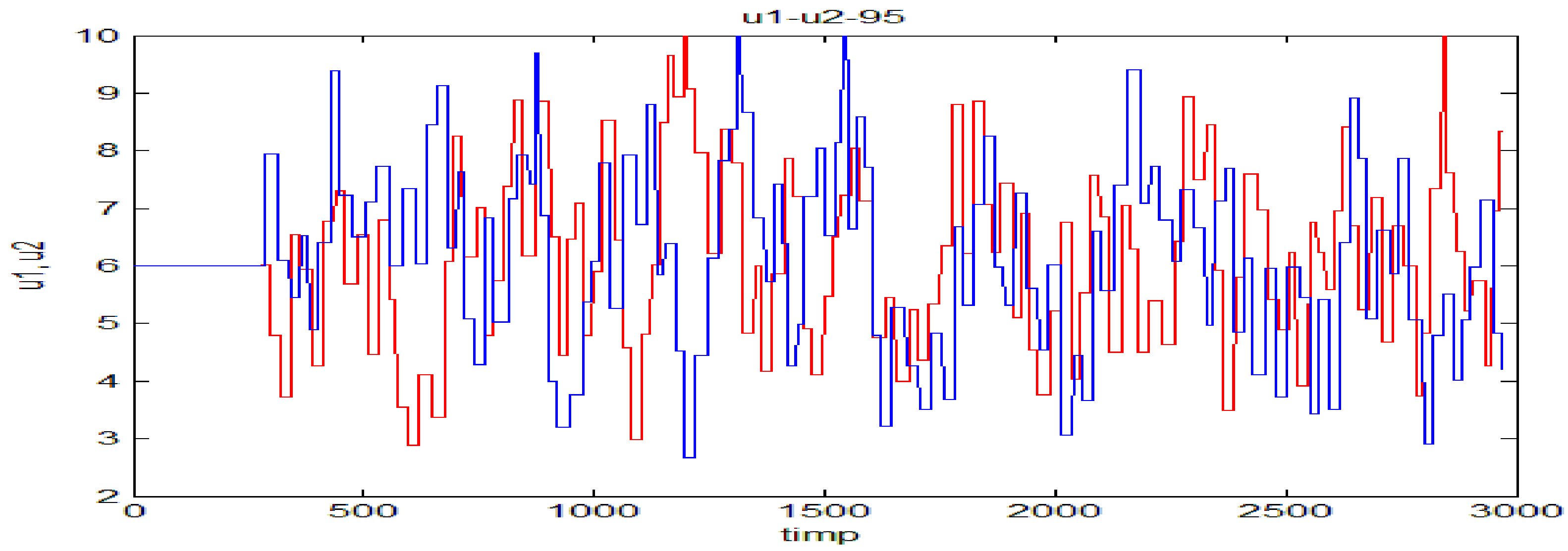
x_zgomot= [nb11,nf11,nb21,nf21,1,1] => Model M2

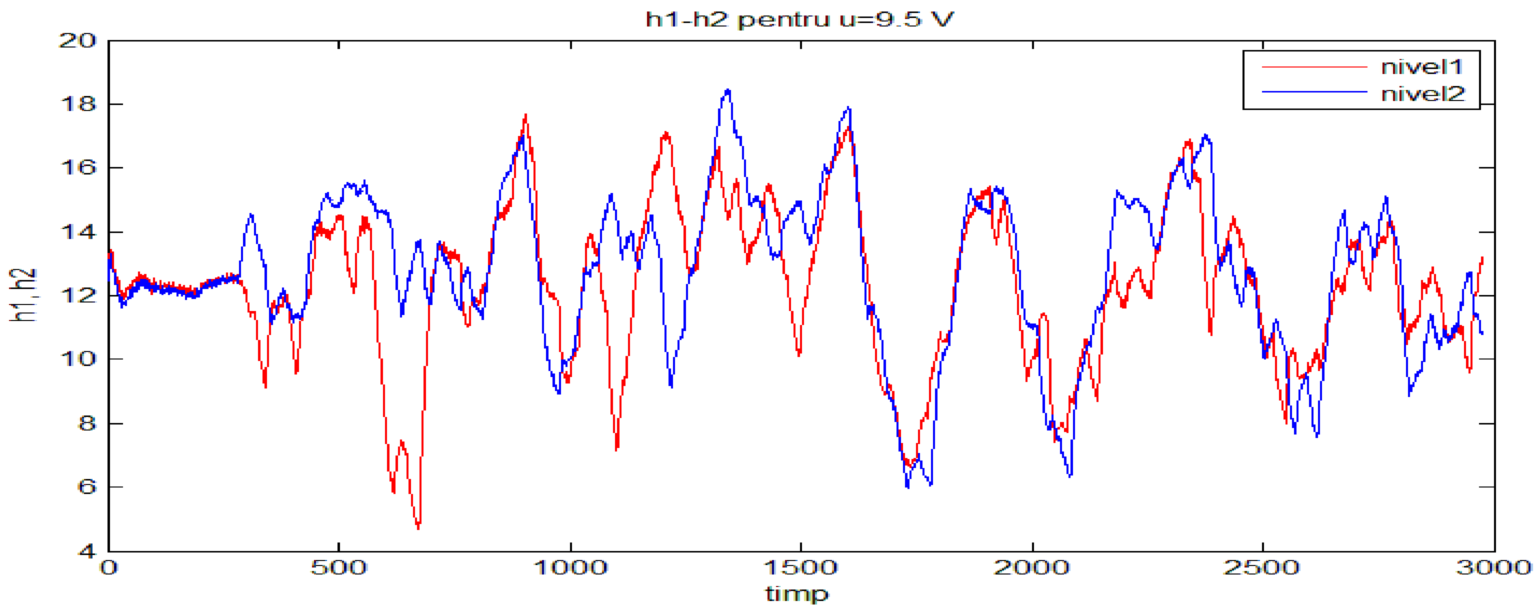
   3.2. v=y_masurat-y_u
   3.3. se estimeaza *e* din $v[n] = \frac{C(q^{-1})}{D(q^{-1})} e[n]$ => model M3

x_zgomot= [nb11,nf11,nb21,nf21,nc1,nd1]

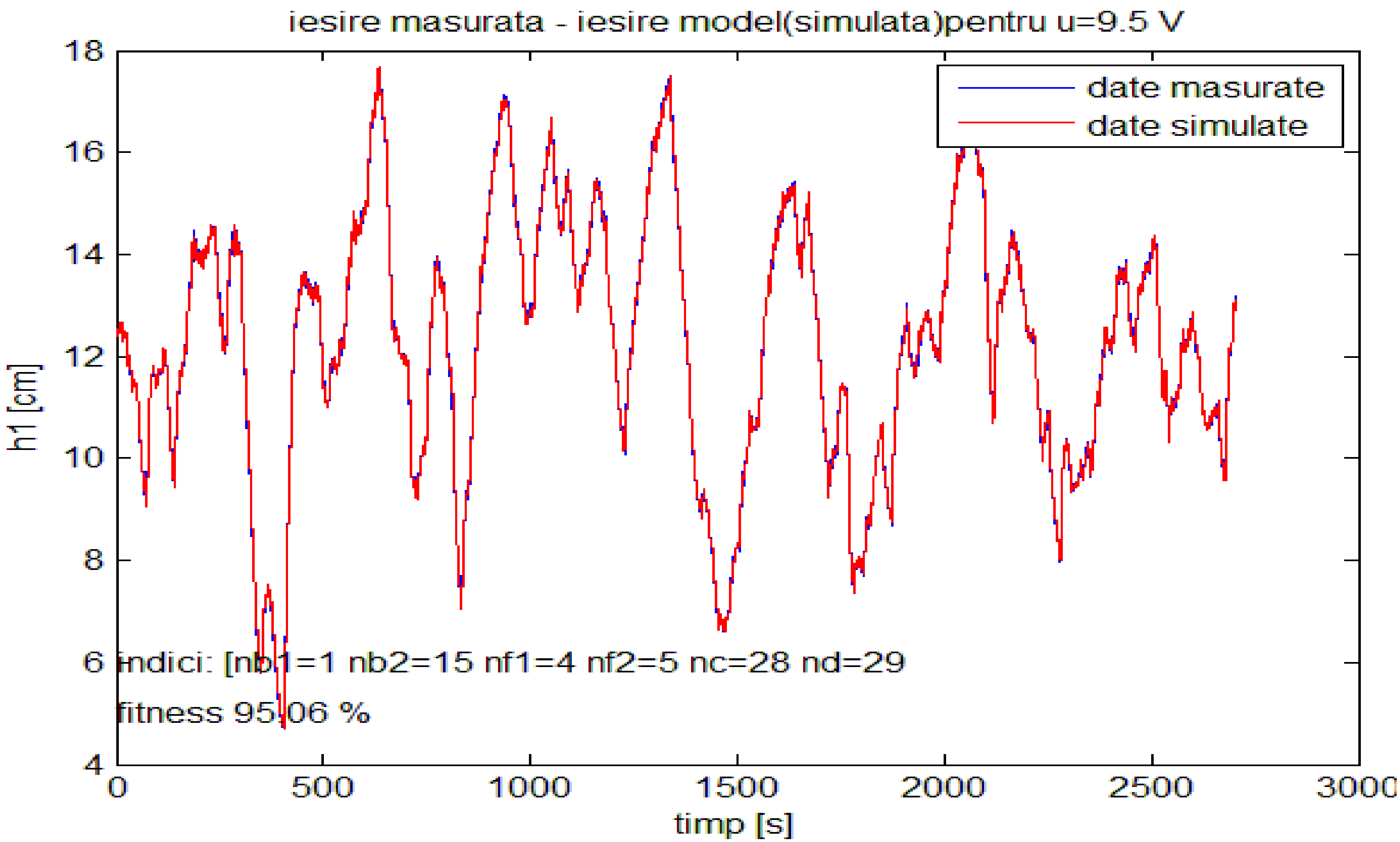
4. Model final [nb1,nf1,nb2,nf2,nc,nd, nb11,nf11,nb21,nf21,nc1,nd1]

6. Rezultatele simularilor (1)

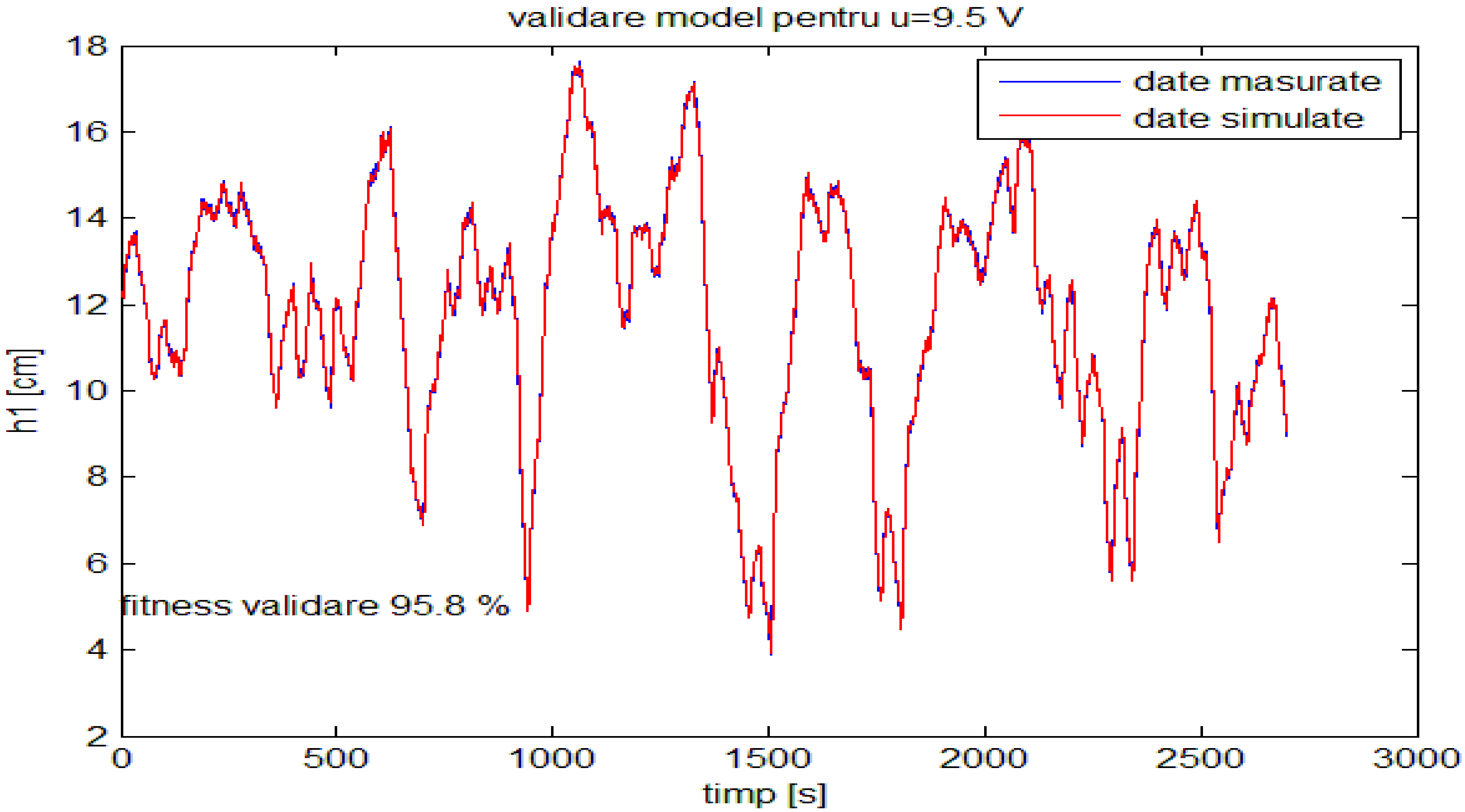




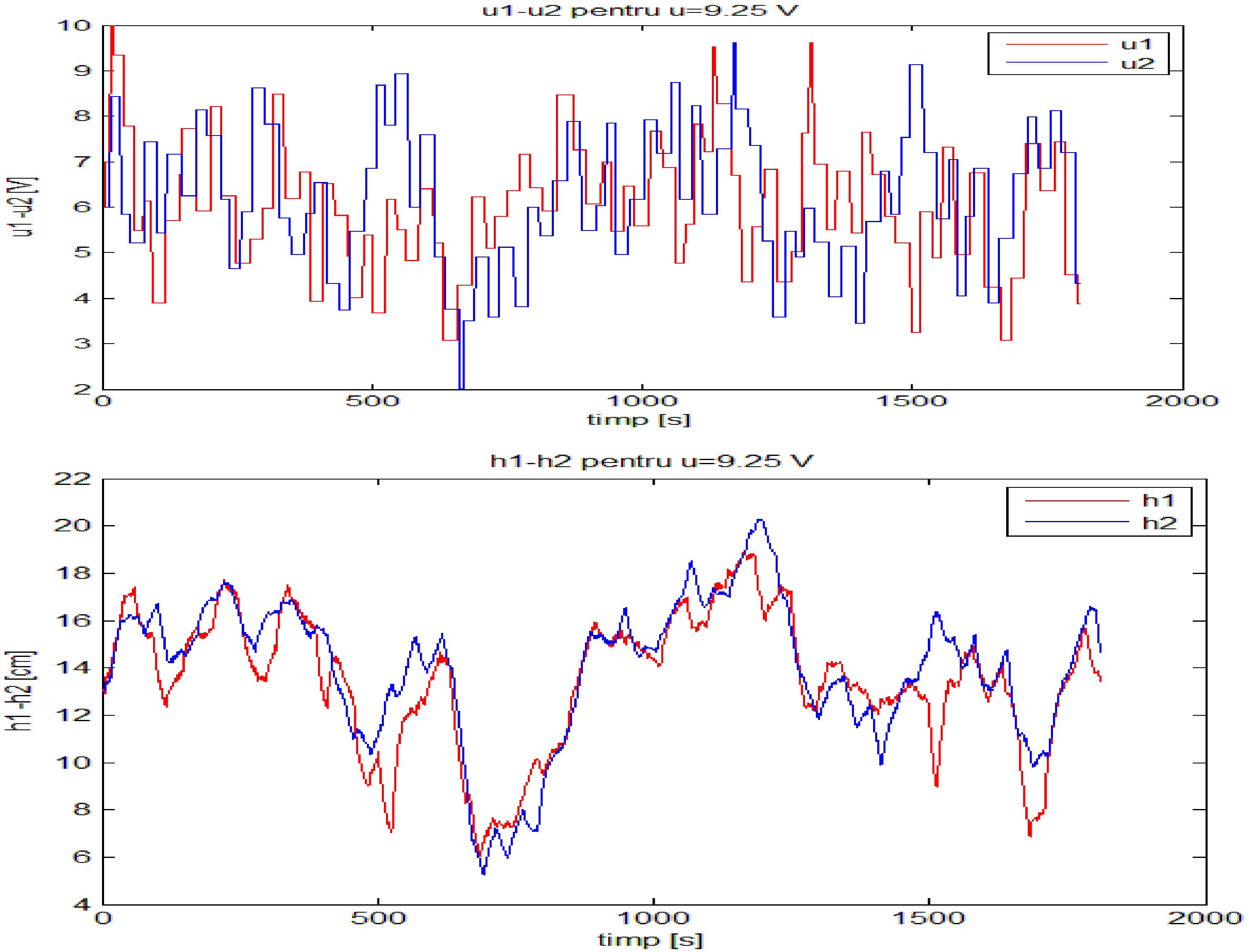
6. Rezultatele simularilor (2)



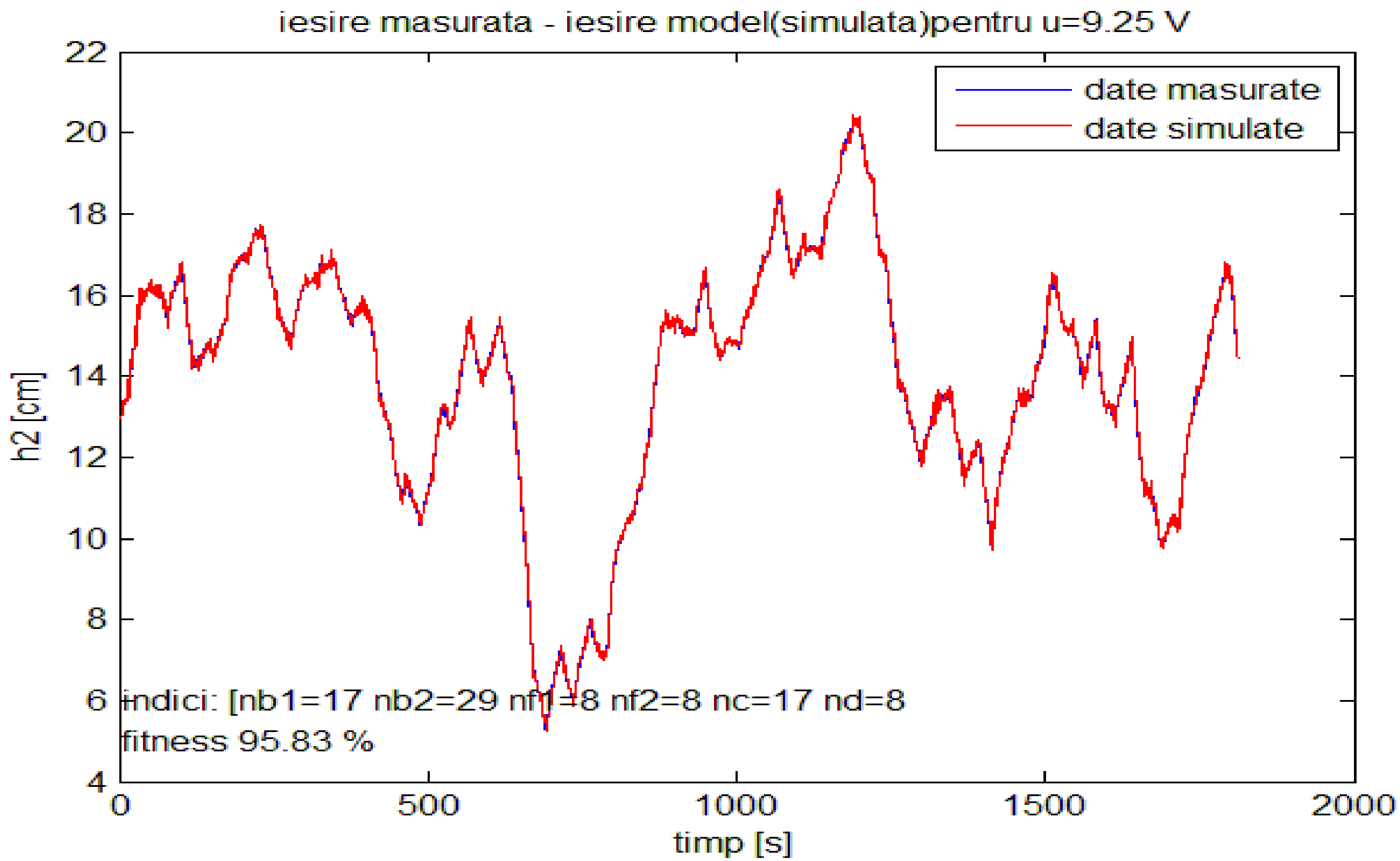
6. Rezultatele simularilor (3)



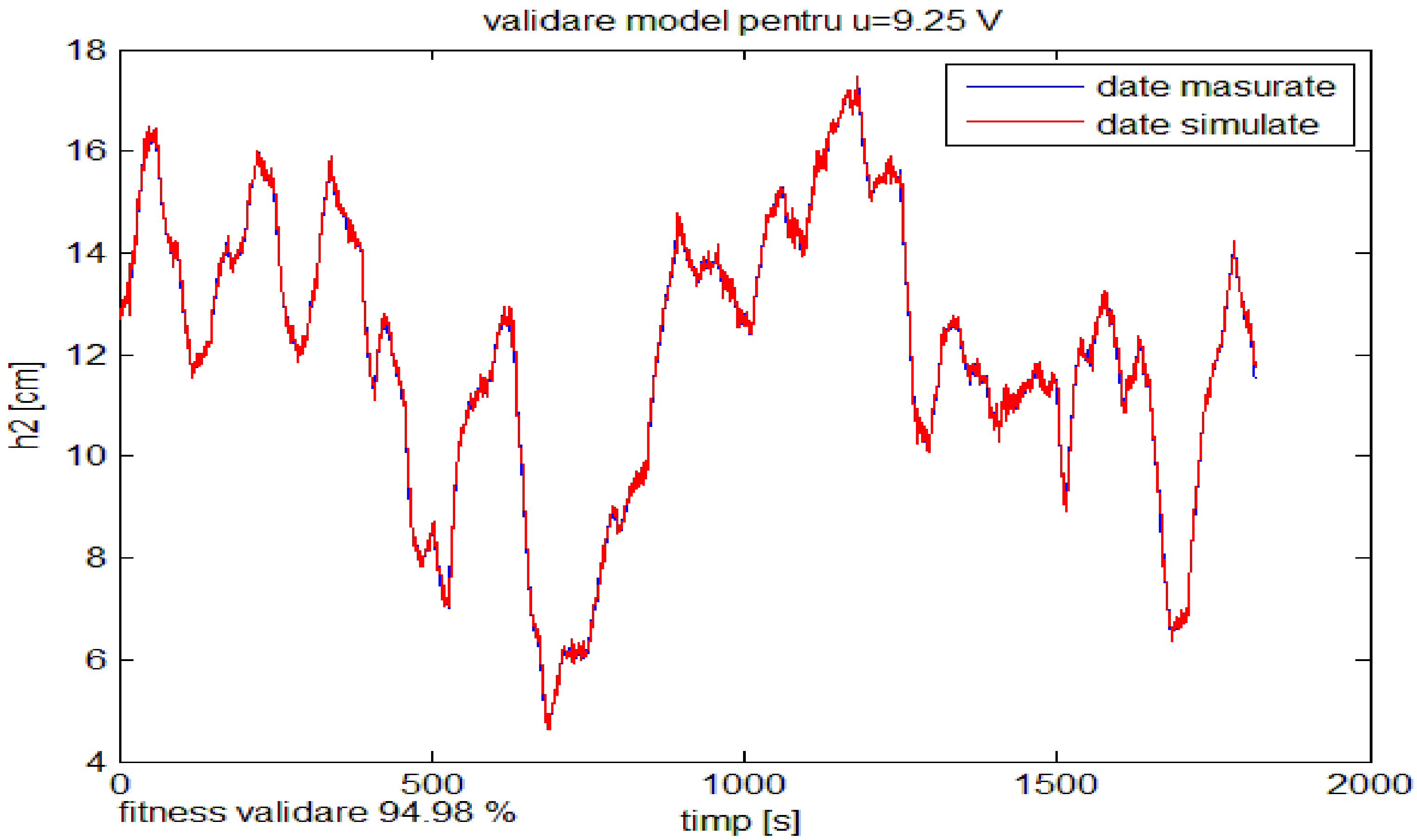
6. Rezultatele simularilor (4)



6. Rezultatele simularilor (5)



6. Rezultatele simularilor (6)



7. Concluzii si directii de cercetare viitoare

- ASTANK2 este o instalatie versatila, care ofera posibilitatea efectuarii unei game largi de experimente si care permite, de asemenea, amplasarea de senzori suplimentari in acest scop;
- O parte din modelele propuse (analitic si experimental) au fost validate pe cale experimentala;
- Proiect depus (PED Proiect experimental – demonstrativ) :

  An Integrated Double Water Tank System
- Cercetari viitoare :
  - Imbunatatirea modelului analitic
  - detectia si izolarea de defecte
  - control optimal

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