ADAPTIVE-FEEDBACK METHOD OF SYNCHRONIZATION FOR ENERGY SYSTEMS

O METODÃ DE SINCRONIZARE DE TIP FEEDBACH A SISTEMELOR ENERGETICE

***OANCEA Servilia*[1], *GROSU I.*[2], *OANCEA A.V.*[3]**

[1]University of Agricultural Sciences and Veterinary Medicine Iasi, Romania

[2]University of Medicine and Pharmacy, Iasi, Romania,

[3]"Al.I. Cuza" University Iasi, Romania

Abstract. *The issue of energy supply and demand has been valued worldwide with increasing development of economy. Energy resource including coal, petroleum, natural gas, water and electricity, and nuclear power etc., can be classified by renewable energy and non-renewable energy according to the capability of sustainable utilization. Energy resource system is a kind of complex nonlinear system, a three-dimensional autonomous system exhibiting very complex dynamical behavior. Researches on the complicated economic systems through nonlinear method have been achieved fruitfully and several authors supposed that both economic system and energy system are chaotic and nonlinear. Over the last decade, there has been considerable progress in generalizing the concept of synchronization to include the case of coupled chaotic systems, especially from technical reasons. In order to formulate the chaos control of the energy systems, in this work the synchronization of two energy systems using an adptive feedback method of synchronization is presented.*

Key words: energy supply and demand, nonlinear system, chaos control

Rezumat. *Problema cererii şi ofertei de energie a fost evaluată peste tot în lume odată cu dezvoltarea economiei. Resursele de energie incluzând cărbune, petrol, gaze naturale, apă şi electricitate, energie nucleară pot fi clasificate în reciclabile şi nereciclabile în funcţie de capacitatea lor de utilizare sustenabilă. Sistemul resurselor de energie este un sistem complex neliniar, un sistem tridimensional autonom care are o comportare dinamică foarte complexă. Cercetările sistemelor economice complicate prin metode nelineare au avut rezultate şi mai multi autori presupun că atât sistemul economic ca şi cel energetic sunt haotice şi neliniare. In ultimele decade există un progres considerabil în generalizarea conceptului de sincronizare pentru a include sistemele haotice, în special din motive tehnice. Pentru a realiza controlul haosului în sistemele energetice, în această lucrare sincronizăm două sisteme energetice folosind o metodă de feedback.*

Cuvinte cheie: cerere şi ofertă de energie, sistem neliniar, controlul haosului

INTRODUCTION

The issue of energy supply and demand has been valued worldwide with increasing development of economy. Energy resource including coal, petroleum, natural gas, water and electricity, and nuclear power etc., can be classified by renewable energy and non-renewable energy according to the capability of sustainable utilization.

Sun and coworkers (Sun, 2006), (Sun, 2007a), (Sun, 2007b) established an energy resource system based on the background of the real energy resources demand supply in the East and the West of China. Energy resource system is a kind of complex nonlinear system, a three-dimensional autonomous system exhibiting very complex dynamical behaviors. The authors presented the situation of energy supply and demand in a province in East China, one of the provinces whose energy resources are severely insufficient. Nevertheless, the West regions of China are rich in energy resources and therefore the Chinese energy resources distribution features make it important to cooperate between East and the West. Researches on the complicated economic systems through nonlinear method have been achieved fruitfully and several authors (Sun, 2006), (Tian, 2007) supposed that both economic system and energy system are chaotic and nonlinear.

Over the last decade, there has been considerable progress in generalizing the concept of synchronization to include the case of coupled chaotic systems, especially from technical and economical reasons. When the complete synchronization is achieved, the states of both systems become practically identical, while their dynamics in time remains chaotic. Many examples of synchronization have been documented in the literature, but currently theoretical understanding of the phenomena lags behind experimental studies (Chen, 1998), (Shiying, 2000), (Yassen, 2005), (Yassen M., 2005), (Grosu I., 1997), (Lerescu, 2004), (Grosu, 2008), (Oancea, 2009a). In order to formulate the chaos control of the energy systems, in this work the synchronization of two energy systems using an adptive feedback method of synchronization is presented.

THEORY

The energy system is (Sun, 2007c) :

$$\begin{aligned}
\dot{x}_1 &= -a_1 x_1 \left(1 - x_1 / M\right) - a_2 (x_2 + x_3) \\
\dot{x}_2 &= -b_1 x_2 - b_2 x_2 + b_3 x_1 [N - (x_1 - x_3)] \\
\dot{x}_3 &= c_1 x_3 \left(c_2 x_1 - c_3\right)
\end{aligned} \tag{1}$$

where $x_1(t)$ the energy resource shortage in *A* region, $x_2(t)$ the energy resource supply increment in *B* region, $x_3(t)$ the energy resource import in *A* region; *ai; bi; ci; M; N* are positive real constants.

This system has a chaotic behavior for :

$M=1.8$, $N=1$, $a_1=0.09$, $a_2=0.15$, $b_1=0.06$, $b_2=0.082$, $b_3=0.07$, $c_1=0.2$, $c_2=0.5$, $c_3=0.4$ (2)

Figure 1 shows that the attractor projected onto x_1x2x3 space for the chaotic system (1) with values from (2) and initial conditions $x_1(0)=0.82$, $x_2(0)=0.29$, $x_3(0)=0.48$.

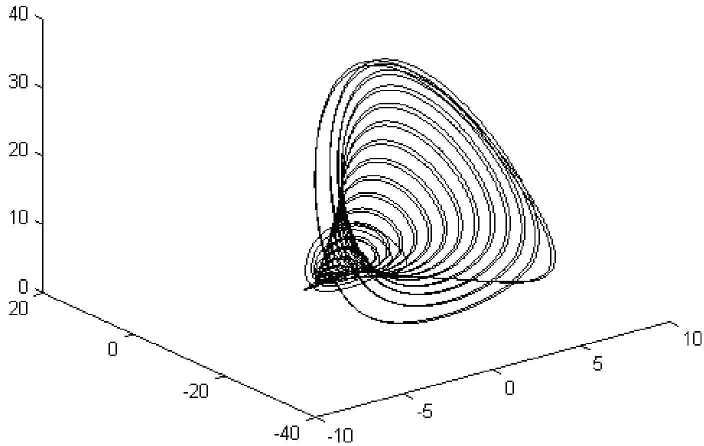

Fig. 1. Phase portrait of (x_1, x_2, x_3) for energy system

To synchronize two energy systems we used a simple method for chaos synchronization proposed by Guo et al. in (Guo., 2009a, 2009b) and used by Oancea (Oancea, 2009b).

If the chaotic system (master) is:

$\dot{x} = f(x)$ where $x = (x_1, x_2, ...x_n) \in R_n$

$f(x) = (f_1(x), f_2(x).....f_n(x)) : R^n \to R^n$

then the slave system is:

$\dot{y} = f(y) + z(y - x)$

where the functions $\dot{z}_i = -\lambda_i (y_i - x_i)^2$ and λ_i are positive constants

RESULTS AND DISCUSSIONS

The slave system for the system (1) is:

$$\begin{aligned}
\dot{y}_1 &= -0.09 y_1 (1 - y_1 / 1.8) - 0.15 (y_2 + y_3) + z_1 (y_1 - x_1) \\
\dot{y}_2 &= -0.06 y_2 - 0.08 y_2 + 0.07 y_1 [1 - (y_1 - y_3)] + z_2 (y_2 - x_2) \\
\dot{y}_3 &= 0.2 y_3 (0.5 y_1 - 0.4) + z_3 (y_3 - x_3)
\end{aligned} \tag{5}$$

The control strength is of the form:

$$\begin{aligned}
\dot{z}_1 &= -(x_1 - x)^2 \\
\dot{z}_2 &= -(y_1 - y)^2 \\
\dot{z}_3 &= -(z_1 - z)^2
\end{aligned} \tag{4}$$

Fig. 2, 3, 4, 5, 6 and 7 show the syncronization of the two energy systems.

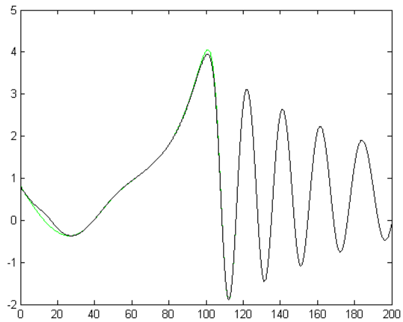

Fig.2. $x_1(t)$- green $y_1(t)$- black [$x_1(0)=0.82$, $x_2(0)=0.29$, $x_3(0)=0.48$; $y_1(0)=0.8$; $y_2(0) = 0.2$ $y_3(0) = 0.5$; $z_1(0)=0.1$; $z_2(0) = 0.1$; $z_3(0) = 0.1$]

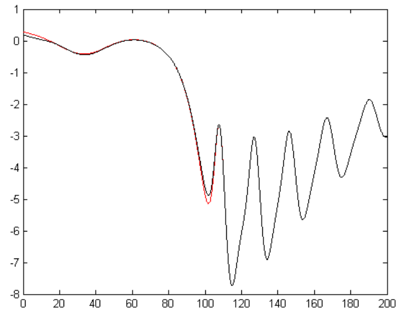

Fig.3. $x_2(t)$- red $y_2(t)$- black [$x_1(0)=0.82$, $x_2(0)=0.29$, $x_3(0)=0.48$; $y_1(0)=0.8$; $y_2(0) = 0.2$ $y_3(0) = 0.5$; $z_1(0)=0.1$; $z_2(0) = 0.1$; $z_3(0) = 0.1$]

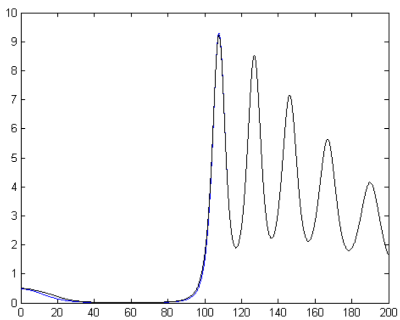

Fig. 4. $x_3(t)$- blue $y_3(t)$- black [$x_1(0)=0.82$, $x_2(0)=0.29$, $x_3(0)=0.48$; $y_1(0)=0.8$; $y_2(0) = 0.2$ $y_3(0) = 0.5$; $z_1(0)=0.1$; $z_2(0) = 0.1$; $z_3(0) = 0.1$]

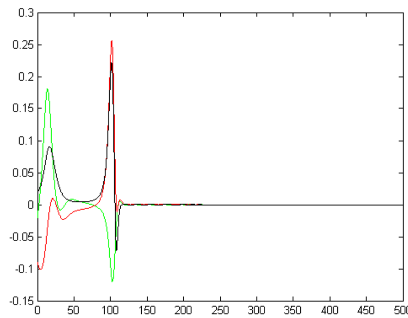

Fig. 5. Synchronization errors between master and slave systems [$x_1(0)=0.82$, $x_2(0)=0.29$, $x_3(0)=0.48$; $y_1(0)=0.8$; $y_2(0) = 0.2$ $y_3(0) = 0.5$; $z_1(0)=0.1$; $z_2(0) = 0.1$; $z_3(0) = 0.1$]

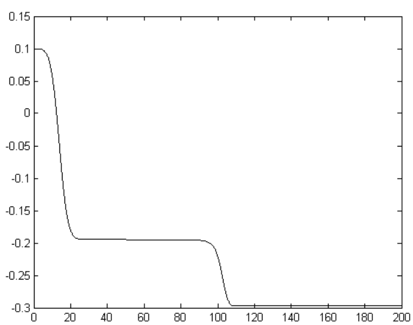

Fig. 6. The control strength z_1[$x_1(0)=0.82$, $x_2(0)=0.29$, $x_3(0)=0.48$; $y_1(0)=0.8$; $y_2(0) = 0.2$ $y_3(0) = 0.5$; $z_1(0)=0.1$; $z_2(0) = 0.1$; $z_3(0) = 0.1$]

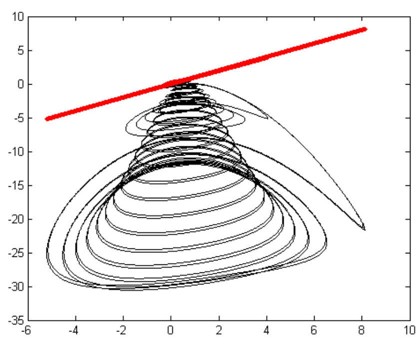

Fig. 7. Phase portrait of (x, x_2) and (x_1, y_1) for energy system [$x_1(0)=0.82$, $x_2(0)=0.29$, $x_3(0)=0.48$; $y_1(0)=0.8$; $y_2(0) = 0.2$ $y_3(0) = 0.5$; $z_1(0)=0.1$; $z_2(0) = 0.1$; $z_3(0) = 0.1$]

Debin Huang (Huang, 2005), by testing the chaotic systems including the Lorenz system, Rossler system, Chua's circuit, and the Sprott's collection of the simplest chaotic flows found that we can use a single controller to achieve identical synchronization of a three-dimensional system (for Lorenz system this is possible only we add the controller in the second equation).

For the system (1), we achieved the synchronization if one controller is applied only in the first equation; the synchronization errors are given in figure 8.

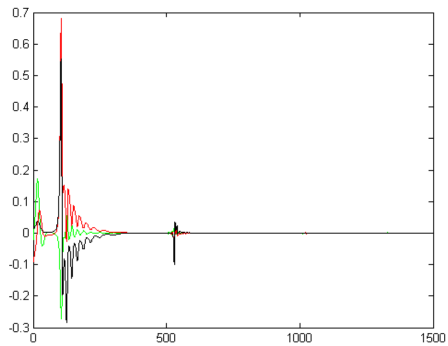

Fig. 8. Synchronization errors between master and slave systems. [$x_1(0)=0.82$, $x_2(0)=0.29$, $x_3(0)=0.48$; $y_1(0)=0.8$; $y_2(0) = 0.2$ $y_3(0) = 0.5$; $z_1(0)=0.1$]

If two controllers are applied, then the synchronization is achieved earlier than for one the controller but later than all controllers have been used (figure 9).

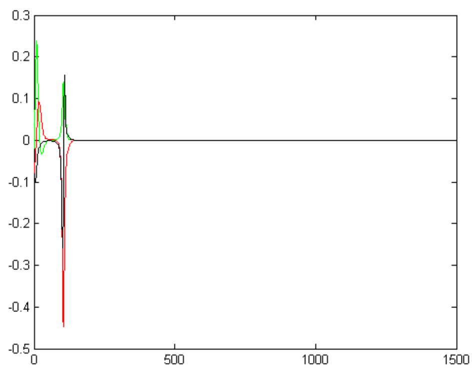

Fig. 9. Synchronization errors between master and slave systems. [$x_1(0)=0.82$, $x_2(0)=0.29$, $x_3(0)=0.48$; $y_1(0)=0.8$; $y_2(0) = 0.2$ $y_3(0) = 0.5$; $z_1(0)=0.1$, $z_3(0)=0.1$]

CONCLUSIONS

In order to formulate the chaos control the synchronization of two energy systems is presented in this work. The transient time until synchronization depends on initial conditions of two systems and the strength and number of the controllers. The control method described in this paper is very easy and might be useful in the case of the other chaotic systems.

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