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1st APTECS 2009

NATIONAL SEMINAR ON APPLIED TECHNOLOGY, SCIENCE, AND ARTS

THE PROCEEDING

Surabaya, Dec. 22, 2009

ITS
Institut Teknologi Sepuluh Nopember

LEMBAGA PENELITIAN DAN PENGABDIAN KEPADA MASYARAKAT

FIND-11

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PROCEEDING

NATIONAL SEMINAR
ON "APPLIED TECHNOLOGY, SCIENCE AND ARTS"
1st APTECS 2009

THEME

KEUNGGULAN PENGELOLAAN SUMBER-SUMBER ENERGI DALAM MENGHADAPI KRISIS SOSIAL-EKONOMI GLOBAL

Graha Sepuluh Nopember, 22 Desember 2009

Organized by:
LEMBAGA PENGABDIAN PADA MASYARAKAT (LPPM)
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
2009

PROCEEDING OF NATIONAL SEMINAR ON APPLIED TECHNOLOGY, SCIENCE, AND ARTS 1st APTECS 2009

Edited by APTECS TEAM

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ISSN 2086-1931

NATIONAL SEMINAR ON APPLIED TECHNOLOGY, SCIENCE, AND ARTS 2009

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SAMBUTAN REKTOR ITS

Assalamu'alaikum Wr. Wb. Salam sejahtera bagi kita semua, semoga Allah SWT selalu melimpahkan rahmat dan karuniaNya kepada kita sekalian. Saya mengucapkan selamat datang untuk peserta ***National Seminar on Applied Technology, Science and Arts*** **(APTECS)** yang telah datang dari dalam maupun luar negeri. Seminar ini merupakan forum komunikasi ilmiah dalam rangka *sharing* ilmu pengetahuan, teknologi dan seni.

Sebagai komponen bangsa, Institut Teknologi Sepuluh Nopember (ITS) ikut menyelesaikan permasalahan bangsa yang menyangkut krisis sosial dan ekonomi melalui pengelolaan sumber-sumber energi yang tepat dan terarah yang merupakan topik APTECS kali ini. Topik APTECS yang pertama ini bersesuaian (*selaras*) dengan 3 (tiga) unggulan penelitian di ITS yaitu, Energi, Permukiman, dan Kelautan.

Energi merupakan salah satu daya dukung penguatan sektor ekonomi dan pembangunan Indonesia. Krisis di sektor riil dan investasi global berimplikasi signifikan pada daya dukung tersebut, dan berdampak pada penurunan kemampuan pemenuhan kebutuhan dasar masyarakat (sandang, papan, dan pangan). Oleh karena itu melalui APTECS yang pertama ini ITS menggagas tentang kesinergian yang berkesinambungan di bidang teknologi, sosial dan ekonomi dalam upaya menghadapi krisis tersebut secara regional maupun global, sehingga pemecahan dan tanggung jawabnya tidak terpisah hanya di satu negara saja, namun menjadi tanggungjawab semua negara. Bentuk sumbangsih ini akan dipresentasikan dalam bentuk diskusi ilmiah yang merangkai berbagai disiplin ilmu di seminar ini.

Dalam kesempatan ini ITS berterima-kasih kesemua pihak (LPPM-ITS, Panitia APTECS, peserta seminar dan semua pihak yang mendukung acara ini). Akhir kata, kami mengucapkan selamat berseminar semoga sukses dan sampai jumpa tahun depan pada 2nd APTECS 2010.

Surabaya, 22 Desember 2009
Rektor ITS

PROF. PRIYO SUPROBO

SAMBUTAN KETUA LPPM ITS

Puji syukur patut kita panjatkan kehadapan Tuhan Yang Maha Esa, yang dengan karunia dan rahmatNya APTECS dapat berjalan dengan baik. Dua ratus enam puluh paper ilmiah terpilih akan dipresentasikan, dan lebih dari 400 peneliti, industriawan, dan akademisi dari dalam negeri dan luar negeri akan hadir untuk menyampaikan ide dan kontribusinya terhadap perkembangan Ilmu Pengetahuan, Teknologi, dan Seni untuk kemaslahatan umat manusia. Prestasi ini patut disyukuri dan dengan usaha yang keras penyelenggara, dan ada kebangkitan kesadaran dari para peneliti selaku *Core Creative Comunity* untuk terus berpartisipasi atmosfir akademika ini.

Seminar ini diselenggarakan oleh LPPM-ITS dalam rangka Dies Natalis ITS yang ke 49 dan menunjang program FIND-11, dan juga dalam rangka membangun jaring dan komunikasi antar peneliti, pelaku industri, dan akademisi di tingkat nasional maupun internasional. Karena salah satu bidang unggulan yang dikembangkan ITS adalah bidang *Energi, pemukiman, dan kelautan,* maka seminar yang pertama ini mengambil tema *Keunggulan Pengelolaan Sumber-sumber Energi dalam Menghadapi Krisis Sosial-Ekonomi Global.*

Sumber daya alam dan sumber daya manusia yang banyak sudah tidak dapat dijadikan modal utama dalam menghadapi persaingan global, tetapi yang sekarang lebih dibutuhkan adalah modal *Ilmu Pengetahuan, Teknologi dan Kreativitas.* Tanpa memiliki tiga modal tersebut maka akan terjadi paradok-paradok yang negatif pada kehidupan yaitu: negara yang berlimpah sumber daya alam, tetapi rakyatnya miskin dan negara dengan banyak sumber daya manusia tetapi menghasilkan nilai tambah yang sangat kecil pada perekonomian dunia. Dalam rangka menguatkan modal Ilmu Pengetahuan, Teknologi dan membangun masyarakat yang kreatif maka LPPM-ITS menyelenggarakan APTECS ini yang akan dikembangkan setiap tahun, dan akan menjadi seminar Internasional di tahun yang akan datang, sehingga dapat menghimpun peneliti-peneliti dunia yang berkualitas dalam mencari pemecahan berbagai persoalan kehidupan umat manusia.

Dalam kesempatan yang berbahagia ini, LPPM-ITS selaku penyelenggara menyampaikan rasa banyak terimakasih dan menyampaikan rasa salut dan berbangga kepada para peneliti yang berpartisipasi. Terimakasih yang sangat dalam juga kami sampaikan kepada pimpinan ITS yang telah mendukung sepenuhnya seminar ini. LPPM-ITS juga merasa patut untuk memberi penghargaan yang tinggi kepada panitia pelaksana yang telah bekerja keras dan cerdas dalam penyiapkan APTECS ini.

LPPM-ITS mengucapkan selamat berpartisipasi dalam seminar, dan teruslah berkarya dan meneliti semoga Tuhan selalu melimpahkan karunia-Nya, sehingga kontribusi yang diberikan oleh para peneliti dapat bermakna untuk kemakmuran, kesejahteraan, dan kemaslahatan umat manusia.

Surabaya, 22 Desember 2009
Ketua LPPM-ITS

PROF. I NYOMAN SUTANTRA

Welcome to APTECS 2009

Assalamu'alaykum warohmatullaahi wabarokatuh

Selamat datang kepada para peserta 1st APTECS, dan semoga Saudara dalam satu hari ini dapat menikmati suasana harmonis di seminar ini dan dapat menikmati keindahan kampus ITS.

Seminar yang dilaksanakan dalam rangka memperingati Dies Natalis ITS ke 49 dan kerjasama FIND-11, sebagai perwujudan dari ajang komunitas para peneliti dan pengkaji bidang Iptek, sosial dan seni yang mengambil tema tahun 2009 *"Keunggulan Pengelolaan Sumber–sumber Energi dalam Menghadapi Krisis Sosial Ekonomi Global.* Di samping tema utama tersebut, beberapa hal yang berhubungan bidang aplikasi teknologi, aplikasi pada sistem pendidikan, aplikasi ICT pada sistem pendidikan, energi dibarukan, efisiensi energi, dan restrukturisasi energi, elektrik, elektronik, bioteknologi, komunikasi dan game technology, transportasi, kebumian dan kebencanaan, manufaktur, material dan proses industri, dan kelautan (biologi laut, bangunan laut dan kepesisiran). Untuk bidang science terdiri dari ilmu sosial dan humaniora, rekayasa sosial, nano science, medical, medicine, pemodelan, komputasi, dan kecerdasan tiruan, nuclear science, seni dan industri kreatif, pendidikan secara umum, pertanian dan kehutanan. Dalam seminar ini akan dilakukan diskusi secara sinergi antara peneliti, praktisi, dan juga dapat diambil sebagai pijakan dalam pengambilan keputusan oleh para pejabat pengambil keputusan, dan juga akan dipresentasikan hasil karya seni anak bangsa sebagai usaha untuk mengangkat karya seni domestik sebagai karya international.

Pada kesempatan ini kami menyampaikan rasa terima kasih kepada Rektor ITS yang memberi semangat dan fasilitas dalam penyelenggaraan APTECS ini, Kepada Ketua LPPM ITS dan keluarga besar LPPM ITS yang sangat mensupport dan mengawal acara ini hingga sukses, dan Kepada seluruh civitas akademika ITS. Kepada para sponsorship yang ikut berpartisipasi dalam menyukseskan acara ini kami menyampaikan rasa terima kasih, semoga kerjasama ini dapat terjalin dengan lebih hangat lagi di waktu yang akan datang. Kepada rekan-rekan panitia, Dr. Aulia, Dr Bambang Sampurno, Dr. Heru Mirmanto, Dr. Tavio, Mr. Hendra Cordova, Ms Kamilia, Mr Tamaji, Ms Listiani, Ms Eftrita, Ms Febriana, Ms Liza, Ms Erni, Ms Syiska, Mr Phonny Aditiawan, dan yang lain yang tidak dapat saya sebut satu-persatu yang telah bekerja dengan semangat luar biasa dengan penuh keceriaan dan loyalitas. Kepada para profesor yang berada di technical program committee, Prof Gamantyo, Prof. Noor Endah, Prof. Ali Altway, Prof Perry Burhan, Prof. Suprapto, Prof Triwulan, Prof Djatmiko, Prof Djauhar M., Prof Endang, Prof Eko Budi, dan Prof IN Pujawan, kami menghaturkan rasa terima kasih yang sangat tinggi dengan kesediaan mereka untuk meluangkan waktu untuk APTECS. Terima kasih kepada Tim Gamelan dari Elektro Budoyo Group pimpinan Pak Joko Susila (Jurusan Teknik Elektro ITS), Tim Tari Ngremo Kolosal pimpinan Pak Solihin Fanani (dari SDM 4 Pucang Surabaya), dan Tari Kiprah Glipang pimpinan Pak Boediono dari PDM Probolinggo yang telah menyumbangkan karya kreativitasnya, semoga dapat menjadi titik tonggak awal kebangkitan kreativitas karya seni Indonesia yang selalu digemari oleh putra-putri Indonesia.

Our special thanksfull to Professor HIYAMA Takashi from Kumamoto Univ., Japan, as Keynote Speaker in this event, and welcome to Surabaya.

Mohon maaf dengan segala kekurangan, dan sampai jumpa di International APTECS, 21 Desember 2010 yang akan datang.

Assalamu'alaykum warohmatullaahi wabarokatuh

General Chair of 1st APTECS 2009

PROF. IMAM ROBANDI

UCAPAN TERIMA KASIH KEPADA

REKTOR ITS

LPPM ITS

REDAKSI MAJALAH IPTEK ITS

KUMAMOTO UNIVERSITY, JAPAN

UNIVERSITAS MUHAMMADIYAH SURABAYA

INSTITUT TEKNOLOGI ADHI TAMA SURABAYA

SMP MUHAMMADIYAH 5 SURABAYA

SD MUHAMMADIYAH 4 SURABAYA

SD MUHAMMADIYAH 26 SURABAYA

PT. TIRA AUSTENITE, TBK

RAJANT CORPORATION

LABORATORIUM UJI MATERIAL-D3 T. SIPIL ITS

SCHEDULE

NATIONAL SEMINAR ON APPLIED TECHNOLOGY, SCIENCE, AND ARTS

1st APTECS 2009

6.40 – 7.40 Registrasi

7.40-8.19 Banjaran Srepeg oleh *Elektro Budoyo*

08.19 – 08.26 MC

08.26 – 08.33 Ngremo Kolosal oleh *SD Muhammadiyah 4 Surabaya & Elektro Budoyo*

08.33 – 08.43 Welcome to APTECS oleh *Prof. IMAM ROBANDI*

08.43 – 08.50 Musik dan Tari Kiprah Glipang oleh *Lembaga Seni dan Budaya PDM Probolinggo*

08.50 – 09.00 Sambutan oleh *Prof. I NYOMAN SUTANTRA (Ka LPPM ITS)*

09.00 – 09.08 Gending Ladrang APTECS oleh *Elektro Budoyo*

09.08 – 09.28 Opening Term oleh *Prof. PRIYO SUPROBO (Rektor ITS)*

09.28 – 09.34 Ladrang Parisuko oleh *Elektro Budoyo*

09.34 – 09.40 Launching Buku oleh *Prof. ARIF DJUNAIDY (Pembantu Rektor I ITS)*

09.40 – 10.50 Keynote Speech oleh *Prof. HIYAMA TAKASHI (Kumamoto University, Japan)*

	A	B	C	D	E	F	G	H	I	J
11.00-11.12	ENG-92	ENG-248	ENG-88	MED-13	ENG-219	ENG-245	MED-19	ENG-90	ENG-139	ENG-223
11.12-11.24	ENG-225	SOC-7	ENG-22	ENG-108	ENG-75	ENG-109	SOC-14	ENG-198	ENG-18	ENG-224
11.24-11.36	ENG-134	ENG-40	ENG-144	ENG-85	ENG-77	ENG-129	ENG-233	ENG-199	AGR-4	ENG-201
11.36-11.48	ENG-241	SOC-8	ENG-54	ENG-7	ENG-89	ENG-149	ENG-231	ENG-200	ENG-24	ENG-230
11.48-12.00	ENG-74	ENG-73	ENG-138	ENG-32	ENG-257	ENG-96	AGR-6	ENG-181	ENG-45	ENG-91
12.00-13.00	Break for Lunch									
13.00-13.12	ENG-168	ENG-235	ENG-169	SOC-17	MED-9	ENG-98	ENG-161	ENG-147	ENG-57	ENG-27
13.12-13.24	ENG-171	ENG-172	ENG-124	MED-18	ENG-97	ENG-185	ENG-125	ENG-13	ENG-46	ENG-227
13.24-13.36	ENG-113	ENG-173	ENG-2	ENG-38	ENG-135	ENG-5	MED-20	MED-12	ENG-33	ENG-213
13.36-13.48	ENG-8	ENG-48	ENG-4	ENG-105	ENG-162	ENG-10	ENG-99	ENG-60	ENG-141	ENG-202
13.48-14.00	ENG-86	ENG-21	ENG-115	MED-6	MED-10	ENG-12	ENG-103	ENG-17	ENG-36	ENG-140
14.00-14.12	ENG-87	ENG-132	ENG-55	MED-4	MED-2	ENG-102	ENG-9	ENG-53	ENG-83	MED-17
14.12-14.24	EDU-6	ENG-50	ENG-31	MED-1	ENG-14	ENG-214	ENG-69	MED-8	ENG-68	ENG-165
14.24-14.36	ENG-210	ENG-62	ENG-35	EDU-7	ENG-133	ENG-15	ENG-218	ENG-142	AGR-7	ENG-94
14.36-14.48	ENG-209	SOC-9	ENG-29	ENG-206	ENG-104	ENG-19	MED-5	ENG-64	ENG-112	ENG-146
14.48-15.00	ENG-76	SOC-6	ENG-28	ENG-184	ENG-39	ENG-23	ENG-95	ENG-84	ENG-63	ENG-258
15.00-15.12	ENG-58	ENG-67	ENG-151	SOC-4	ENG-81	ENG-25	ENG-93	ENG-195	ENG-72	ENG-49
15.12-15.24	ENG-79	ENG-6	AGR-8	ENG-56	ENG-42	ENG-187	ENG-59	ENG-107	EDU-4	ENG-80
15.24-15.36	ENG-131	ENG-26	ENG-116	ENG-232	SOC-18	ENG-158	ENG-215	ENG-130	ENG-182	ENG-186
15.36-15.48	ENG-166	ENG-237	SOC-13	ENG-65	ENG-121	ENG-127	ENG-216	ENG-175	ENG-110	ENG-174
15.48-16.00	ENG-128	ENG-164	SOC-12	ENG-34	ENG-156	EDU-1	ENG-137	ENG-119	ENG-37	EDU-2
16.00-16.12	ENG-159	ENG-160	ENG-20	ENG-51	ENG-61	ENG-243	ENG-16	MED-3	ENG-3	ENG-111
16.12-16.24	SOC-10	SOC-5	MED-16	ENG-1	ENG-179	ENG-244	ENG-212	ENG-52	ENG-178	ENG-191
16.24-16.36	ENG-249	ENG-44	ENG-30	ENG-247	MED-21	ENG-192	EDU-5	ENG-177	ENG-193	ENG-228
16.36-16.48	MED- 11	ENG-157	ENG-152	ENG-153	ENG-255	ENG-196	ENG-154	SOC-3	EDU-3	ENG-123
16.48-17.00	ENG-71	ENG-194	ENG-203	Eng-208	ENG-253	ENG-211	ENG-220	ENG-197	MED-7	ENG-221
17.00-17.12	ENG-260	ENG-242	ENG-238	ENG-240	ENG-259	SOC-15	SOC-16	ENG-250	SOC-19	ENG-251
17.12-17.24			ENG-254	ENG-252		ENG-183	ENG-246	ENG-256		

- NOTE

- A : Ruang Argopuro 1 (Lt. 1)
- B : Ruang Argopuro 2 (Lt. 1)
- C : Ruang Kawi (Lt. 1)
- D : Ruang Lawu (Lt. 1)
- E : Ruang Semeru 1 (Lt. 1)
- F : Ruang Semeru 2 (Lt. 1)
- G : Ruang Anjasmoro 1 (Lt. 2)
- H : Ruang Anjasmoro 2 (Lt. 2)
- I : Ruang Anjasmoro 3 (Lt. 2)
- J : Ruang Kelud (Lt. 2)

- 11.32 is time for Dzuhur prayer, 14.58 is time for Ashar prayer.

Moderator Sesion 1 (10.00 – 12.00)

A	Ruang Argopuro 1 (Lt.1)	Prof. Agus Rubiyanto
B	Ruang Argopuro 2 (Lt. 1)	Prof. Djauhar Manfaat
C	Ruang Kawi (Lt. 1)	Prof. Basuki Widodo
D	Ruang Lawu (Lt. 1)	Prof. Djatmiko Ichsani
E	Ruang Semeru 1 (Lt. 1)	Prof. Suprapto
F	Ruang Semeru 2 (Lt. 1)	Prof. Sutardi
G	Ruang Anjasmoro 1 (Lt. 2)	Prof. Paulus Indiyono
H	Ruang Anjasmoro 2 (Lt. 2)	Prof. Noor Endah B. Mochtar
I	Ruang Anjasmoro 3 (Lt. 2)	Prof. Nyoman Pujawan
J	Ruang Kelud (Lt. 2)	Prof. Mauridhi Hery Purnomo

Moderator Sesion 2 (13.00 – 17.00)

A	Ruang Argopuro 1 (Lt.1)	Dr. Agus Purwanto
B	Ruang Argopuro 2 (Lt. 1)	Dr. Achmad Arifin
C	Ruang Kawi (Lt. 1)	Dr. Bambang Lelono
D	Ruang Lawu (Lt. 1)	Dr. Sigit Darmawan
E	Ruang Semeru 1 (Lt. 1)	Dr. Endah Wahyuni
F	Ruang Semeru 2 (Lt. 1)	Dr. Djoko Purwanto
G	Ruang Anjasmoro 1 (Lt. 2)	Dr. Ketut Eddy Purnama
H	Ruang Anjasmoro 2 (Lt. 2)	Dr. Surya Rosa Putra
I	Ruang Anjasmoro 3 (Lt. 2)	Dr. Sri Gunani Pertiwi
J	Ruang Kelud (Lt. 2)	Dr. Prabowo

Aturan Presentasi Seminar

a. Waktu presentasi adalah 12 menit/judul termasuk diskusi.
b. Bel pertama pada menit ke 7, bel kedua pada menit ke 9, sisanya untuk berdiskusi sampai bel ke 3 di menit ke 12.
c. Presenter dimohon untuk efisien dalam menggunakan waktu.
d. Time keeper dimohon sangat ketat dalam menjaga waktu

DAFTAR ISI

EDUCATION

SOCIAL ENGINEERING, SCIENCE, AND ARTS

MEDICAL AND LIFE SCIENCE

AGRICULTURE AND ENVIRONMENT

ENGINEERING

EDUCATION

SOCIAL ENGINEERING, SCIENCE, AND ARTS

MEDICAL AND LIFE SCIENCE

AGRICULTURE AND ENVIRONMENT

Controller Design of Chua's Circuit by Sliding Mode Control and LMI

TAMAJI, MUSYAFA A., AGUS DARMA, IMAM ROBANDI

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Abstract— **In this paper, we studied controller design of Chua's circuit which is chaos system. This system contents the non linear part and we applied the sliding mode control as design controller. Here, it is given the dynamic compensator to avoid the chattering in the sliding mode control. The dynamical compensator is design by using the linear matrix inequality (LMI). The simulation has been done by Matlab. Some of dynamic compensator is tried to observe the performance of system.**

Keywords— **Chaos control, sliding mode control, dynamic compensator, LMI**

1. Introduction

The study of chaos system has been done by some researchers. The chaos is happen because the system has certain parameter, and if the parameter has little changes then the system performance is changing and uncontrollable For long time ago, it is stated that the chaos is unpredictable and uncontrollable. But in 1990, Ott did research in the chaos system [1], and after that a lot of research are doing in various fields. Chua's circuit and Lorenz system are chaos systems. In 2007, [2] studied the chaos synchronization by control based on the three diagonal structure, and [2] studied the synchronize method of fractional Lorenz system, Chen system and Chua's circuit.

Sliding mode control is one of the controller design method which is used in a lot of area. The sliding mode controller is applied in the chaos system [1]. The sliding mode controller is adopted for the robust design controller of uncertain system, because the sliding mode controller is easy o apply, has a quick response, has good transient performance and insensitivity in plant parameter and external disturbance [1].

Usually, the process has two steps, those are design Of sliding surface to assure that the sliding mode equation is stable, and the second is the controller design to drive the state system to sliding surface in finite time. In recent year, variable structure design technique of sliding mode is a popular method in chaos system. Such as [3] studied the chaos control by using sliding, mode theory, and also [4].

In sliding mode controller usually the chattering is happen, the chattering disturbs the performance of system. [1] proposed the new reached law and derived the continue controller to reduce the chattering phenomena. The parameter of sliding surface is obtained by solving the linear matrix inequality (LMI). To handle the linearity part, [1] give the dynamic compensator such that the stability of system is increased.

In this paper, we applied the sliding mode controller to Chua's Circuit, we derive the feedback control, the LMI by using the Lyapunov stability theorem. We choose some value of dynamic compensator and sliding coefficient such that the LMI is satisfied. Some simulation are made by Matlab program. The performance of Chua's circuit system is observed.

2. Mathematical Model of Chua's Circuit.

The Chua's Circuit is a simple electronic circuit made of two capacitors, one linear resistor, one inductor ad one non linear diode [5]. Suppose x_1, x_2, x_3 is a current through the inductor, a voltage across capacitor C_1 and across the inductor and the voltage across the capacitor C_2, respectively then system can be written as mathematical model [1]:

$$\begin{aligned} \dot{x}_1(t) &= -x_1 + x_2 + x_3 \\ \dot{x}_2(t) &= -\beta x_1 + u_1 \\ \dot{x}_3(t) &= \alpha(x_1 - x_3 - g(x_3)) + u_2 \end{aligned} \qquad (1)$$

with non linear part

$$g(x_3) = nx_3 + \frac{1}{2}(m-n)(|x_3+1| - |x_3-1|)$$

The chaos will be happen if the value of parameters are

$\alpha = 40, \beta = 93.333, m = -1.139, n = -0.711$

and $u_1 = u_2 = 0$.

The system Eq (1) can be written as state space system

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -1 & 1 & 1 \\ -\beta & 0 & 0 \\ \alpha & 0 & -\alpha \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ -\alpha g(x_3) \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} \qquad (2)$$

And we can write as general equation

$$\dot{x}(t) = Ax + f(x) + Bu \qquad (3)$$

The system (2) and (3) is unstable. Now, we design the controller such that those system are stable. Here we use the sliding mode controller as design control and we observe the system performance.

3. Sliding Mode Controller

The sliding mode controller method, usually has two steps. The first one is the design sliding surface and the second is the design controller such that the states of system reach the sliding surface.

3.1. Sliding Surface Design

Suppose the sliding surface is

$$s = Cx + z \qquad (4)$$

where $C, s, x, z,$ are matrix which is determined, sliding surface, state variable, the state dynamic compensator, respectively. The state dynamic compensator satisfied:

$$\dot{z} = Kx - z \qquad (5)$$

Matrix K will be determined by solving the linear matrix inequality (LMI).

If we take the differential of sliding surface in Eq (5) respect to system Eq (3) we obtained

$$\dot{s} = C\dot{x} + \dot{z} = CAx + Cf(x) + CBu + Kx - z \qquad (6)$$

In sliding surface, $\dot{s} = 0$ so that we get the control equivalent

$$u_{eq} = (CB)^{-1}(-CAx - Cf(x) - Kx + z) \qquad (7)$$

The matrix C will be determined and satisfies $CB = I$ such that control equivalent become

$$u_{eq} = -CAx - Cf(x) - Kx + z \qquad (8)$$

We substitute the equation (8) to equation (3) then we get

$$\begin{aligned} \dot{x} &= Ax + f(x) + B(-CAx - Cf(x) - Kx + z) \\ &= \{A - BCA - BK\}x + Bz \end{aligned} \qquad (9)$$

In sliding surface, we know that $s = 0$ so that $z = -Cx$ and equation (9) can be written as

$$\begin{aligned} \dot{x} &= \{A - BCA - BK\}x - BCx \\ &= \{A - BCA - BK - BC\}x \\ &= \{A - B(K + C + CA)\}x \end{aligned} \qquad (10)$$

Suppose matrix, $M = -(K + C + CA)$ then the equation (10) can be written as

$$\dot{x} = (A + BM)x \qquad (11)$$

According the control theory, if (A,B) is controllable then there is always exist the matrix M such that matrix $A + BM$ negative definite ($A + BM < 0$). And the eigen value of matrix $A + BM$ can be place in half left plane or have a negative real part. Therefore, we can adopt the pole assignment method to obtain matrices K,C . The matrices K and C can be obtained by solving the linear matrix inequality (LMI). The LMI is derived from the Lyapunov stability criteria.

Suppose a vector $V(x) = x^T x$ is a Lyapunov function candidate of equation (11). The system (11) is stable if satisfies:

a. $V(x,t) \geq 0,\ V(0,t) = 0$

b. $\dot{V}(x,t) < 0$

We know that $V(x) = x^T x > 0$ and

$$\dot{V} = \dot{x}^T x + x^T \dot{x} \qquad (12)$$

Substitute from equation (11) to equation (12) we get

$$\dot{V} = (A - B(K + C + CA))x)^T x$$
$$+ x^T (A - B(K + C + CA))x$$

or

$$\dot{V} = x^T (A^T - K^T B^T - C^T B^T - A^T C^T B^T$$
$$+ A - BK - BC - BCA)x \qquad (13)$$

Suppose

$$\Omega = A^T - K^T B^T - C^T B^T - A^T C^T B^T$$
$$+ A - BK - BC - BCA$$

Then we can write equation (13) as $\dot{V} = x^T \Omega x$.

If $\Omega < 0$ (negative definite) then $\dot{V} < 0$ that is mean the system (11) asymptotical stable. The inequality

$$A^T - K^T B^T - C^T B^T - A^T C^T B^T$$
$$+ A - BK - BC - BCA < 0 \qquad (14)$$

is known as linear matrix inequality (LMI).

Now, we must determine matrices C and K such that the matrix inequality $\Omega < 0$ satisfies.

In the Chua's circuit equation (2) we have matrices

$$A = \begin{bmatrix} -1 & 1 & 1 \\ -\beta & 0 & 0 \\ \alpha & 0 & -\alpha \end{bmatrix}, B = \begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix},$$

$$C = \begin{bmatrix} C_{11} & 1 & 0 \\ C_{21} & 0 & 1 \end{bmatrix}, K = \begin{bmatrix} k_{11} & k_{12} & k_{13} \\ k_{21} & k_{22} & k_{23} \end{bmatrix},$$

So that we get

$$\Omega = \begin{bmatrix} -2 & 1-k_{11} & 1+k_{21} \\ -k_{11}+1 & -2k_{12}-2C_{11}-2 & -k_{13}-C_{11}-k_{22}-C_{21} \\ -k_{21}+1 & -k_{22}-C_{21}-k_{13}-C_{11} & -2k_{23}-2C_{21}-2 \end{bmatrix}$$

By Liapunov stability criteria, if matrix Ω negative definite then the system (11) asymptotical stable. The value of matrices C and K such that matrix Ω negative definite that is mean we solve the linear matrix inequality-LMI equation (14).

3.2. Design Controller

According [1], suppose we take the reached law

$$\dot{s}(t) = -\left(\mu + \eta \| s \|^{\upsilon - 1}\right) s, 0 < \gamma < 1, \mu, \eta > 0$$

Then the state variable $x(t)$ will reach the sliding surface $\{x \mid s = 0\}$ in finite time, and by applying the control vector

$$u = -CAx - Cf - Kx + z - \left(\mu + \eta \| s \|^{\gamma - 1}\right) s \qquad (15)$$

Then the state of system (11) from arbitrary initial condition will toward to sliding switching and reach the sliding surface in finite time [1].

So, the system (2) or (3) will be asymptotical stable if we apply the control input (15) with value of matrices C and K satisfies equation (14).

4. Simulation Result

In this simulation we take the parameter as follows [5] $\alpha = 40, \beta = 93.333, m = -1.139, n = -0.711$, the initial state $(x_1(0), x_2(0), x_3(0)) = (1,0,-1)$ and the initial compensator state $(z_1(0), z_2(0)) = (1,-2)$, parameter $\mu = 1$, $\eta = 2$, $\gamma = \frac{1}{2}$. Here we take some values of C and K which is satisfies equation (14). For case 1

$$C = \begin{bmatrix} 31 & 1 & 0 \\ -40 & 0 & 1 \end{bmatrix}; K = \begin{bmatrix} 1 & -30 & 30 \\ -1 & 2 & 50 \end{bmatrix}$$

The inequality (14) is satisfies and the system asymptotical stable. Figure 1a. shows the performance of Chua's circuit without control (u=0). The system (2) is unstable, but after we applied the sliding mode control with dynamical compensator, the system is asymptotical stable (Fig. 1b.). Figure (1c) shows the Chua's circuit system with control in three dimensional. The control input is showed in Figure (1d).

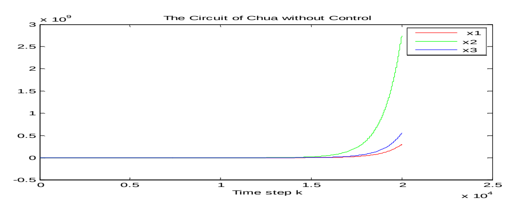

Figure 1a. The system without control

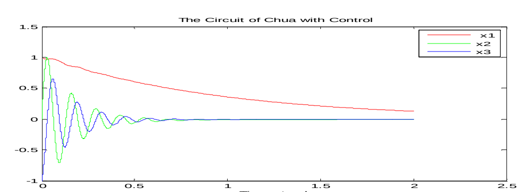

Figure 1b. The system with control

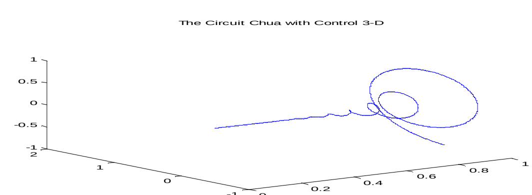

Figure 1c. The system with control 3-D

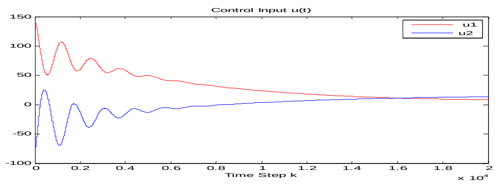

Figure 1d. Control input u(t)

For case 2:

$$C = \begin{bmatrix} 3 & 1 & 0 \\ -4 & 0 & 1 \end{bmatrix}; K = \begin{bmatrix} 1 & -3 & 3 \\ -1 & 2 & 5 \end{bmatrix}$$

The performance Chua's circuit with control is showed Figure 2a. The system with control in three dimension is showed Figure 2b. and the control input vector is showed Figure 2c.

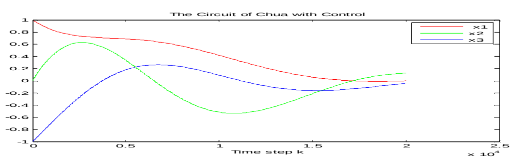

Figure 2a. The system with control

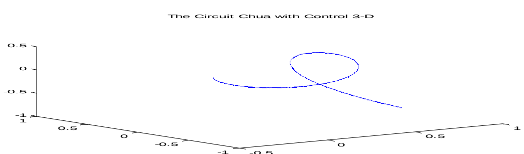

Figure 2b. The system with control 3-D

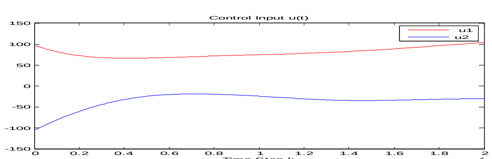

Figure 2c. The control input vector u(t)

For those case 2, the performance is go to stable condition slower than the case 1.

For case 3:

$$C = \begin{bmatrix} 71.4856 & 1 & 0 \\ -137.935 & 0 & 1 \end{bmatrix};$$

$$K = \begin{bmatrix} 1 & -70.9894 & 33.2247 \\ -1 & 3.2247 & 138.4314 \end{bmatrix}$$

The value of C and K are taken from [1]. For this case, Figure 3a. shows the Chua's circuit with control. System (2) converge to zeros, with an oscillation. Case 1 and Case 2 have less oscillation than case 3. The Figure 3b. is a system state in three dimension, and the Figure 3c. shows the control input u(t). This input has a sinusoidal form.

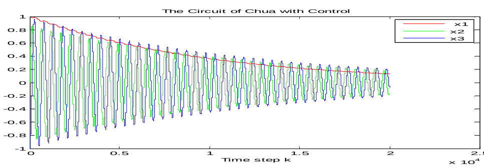

Figure 3a. The Chua's circuit with control

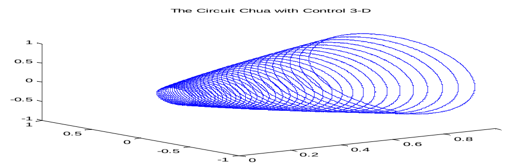

Figure 3b. The Chua's circuit with control in 3-D

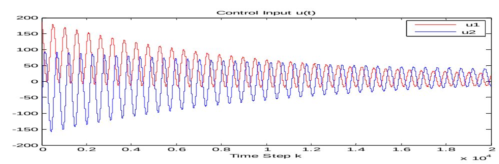

Figure 3c. Control input u(t)

From those simulation, we know that the value of C and K are influenced the stability of system. The control input u(t) also influences the system behavior. If the input control with sinusoidal form, give the behavior system is also has the sinusoidal form. The performance of case 1 is the best of three cases, because the system toward the stability condition with less oscillation.

5. Concluding Remark

From those discussion and the simulation, we conclude that:

a. The sliding mode control with dynamical compensator can be used as controller design for non linear system the Chua's circuit.
b. The value of sliding coefficient C and the dynamic compensator K can be determined by solving the LMI which is derived from the Liapunov stability criteria.
c. The values of C and K are influence the speed of the system become stable
d. The performance of case 1 is better than the others. Because case 1 has less oscillation, and faster to go stable position.

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