Wavelet Based Optimal Control Solution for Nonlinear Systems

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Abstract

The main objective of the research is to show the advantages of wavelet based method from conventional ones to solve a nonlinear problem in a photovoltaic solar power generation. This nonlinearity comes from a case of limited power of solar radiation and expensive cost of solar panel, therefore maximization of absorbed power become important.

To solve the problem, the system state space approach is used. The optimal control problem is transformed and reduced to a boundary value problem using Hamiltonian equation derivation. To increase computation speed, a wavelet analysis is used as time discretization adaptation on numerical solver that uses time discretization basis. The wavelet is employed as analysis tool at each discretization level, start from coarse to finer discretization. The temporary grid result at present level is then used for determining the next level discretization.

The final results of determining maximum power, prove that optimal control scheme can be used to solve control problem of solar power generation. The computation results also show that computation speed increases significantly by employing wavelet adaptation on the conventional solver without decreasing its accuracy.

Key words: optimal control, nonlinear system, wavelet analysis

1. Introduction

In general nonlinear system is any problem with variables that can be represented as linear summation from independent components. Nonlinear system can be classified by natural nonlinear system and intended nonlinear system i.e. for special purposes. Example for this is optimal control. Research for control system with nonlinear approach has been investigating more and more use to most real system is nonlinear (Ogata, 1996, and Wikipedia, 2008).

In the other hand, most of nonlinear problem can not be solved with analytical method but should require numeris methods. Unfortunately numerical method has a drawback in longer computational time. Optimal control technique is a process for determining control signal and state trajectory in dynamical systems along certain time period for minimizing performance index. Then a numerical solver can be applied after the optimal control problem converted into a boundary value problems (BVP) i.e. differential equation problem with some constrained in initial, end, or the trajectory (Bonnard and Caillau, 2006 and Becerra, 2008).

Current Algorithms for control grow along with signal processing algorithms. A relatively new algorithm called Wavelet appears in nonlinear signal recognition and processing. Some researches show that Wavelet based algorithm is suitable for signal processing that has non linearity (Pereyra and Mohlenkamp, 2004).

The objective of the research is to compare some conventional method with wavelet based method to solve an optimal control problem that found in a photovoltaic solar power generation control. This problem appears due to limited power of solar radiation and expensive cost of solar panel, therefore maximization of absorbed power become important.

2. Literature Review

Park and Scheeres (2003) shows that solving optimal control problem can be done through Boundary value problem (BVP). BVP can be derived from Hamiltonian equations.

In signal analysis Wavelet method is a relatively new compare to popular Fourier analysis. Gargour and
Ramachandran (1997) give basic Wavelet theory. The basic different between Wavelet and Fourier is that Wavelet is more suitable for non-periodic signal analysis, e.g. signal that have non linearity.

A research by Caillau and Noailles (2000) discusses BVP solution in general with help of wavelet computation in time discretization algorithm basis. The wavelet contribution is at time discretization shooting that used in multiple-shooting method. Each iteration discretization is repeated and adapted according to wavelet analysis in previous iteration solution.

Mahout and Boitier (2003) propose a model with state equation of a quadratic nonlinear solar power system. But they still use method of partial linearization to get the control signal. Some techniques to reach the maximum power in solar power generation system have largely discussed. According to Esram and Chapman (2006), there are hundreds of research or manuscripts about that from 1968 to 2005. Three techniques that mostly use is Hill-climbing or perturb and observe (PO), incremental conductance and fractional open-circuit voltage. PO is a method that gives specific reference voltage and observes current change at a solar array or module.

Most of the method is based on linear approximation. But there is a nonlinear method that has better accuracy due to most of the real cases is nonlinear in nature. Most nonlinear problem cannot be solved analytically and mostly use numerical approach. The famous nonlinear system solver is based on newton method. It usually uses single shooting or multiple shooting schema. Some other methods also available, one of them is the collocation method. This method is currently available to solve ordinary differential equation, partial differential and integral equations. The basic idea is to choose limited dimension space from solution candidate (usually polynomials up to some level) and several points in a domain (namely collocation points) and chooses the solution that fulfill the given equation at the collocation points (Wikipedia, 2008).

Boundary Value Problems solver that base on time discretization i.e. multiple shooting newton method and collocation method need time slicing to smaller parts. Each small part could have different dynamic phenomena. Therefore a non uniform slicing or adaptation is likely to be appropriate method. This adaptive method can be done using wavelet.

2. System Modeling

Overall system e.g. solar cell, power converter, and load compose solar photovoltaic power generation that is shown in figure 1.

![Figure 1. Model of solar photovoltaic power generation system](image)

Suppose $i_L$ and $v_c$ are state variable and each is noted as $x_1$ and $x_2$, the state equation for boost converter can be written as:

$$
\begin{align*}
    \dot{x}_1 &= \frac{V_p}{L} \frac{u}{L} x_2 \\
    \dot{x}_2 &= -\frac{1}{C_s r_B} (x_2 - V_B) + \frac{u}{C_s} x_1
    
\end{align*}$$

If optimal control is defined by solar power maximization $P_p$, then

$$
P_p = V_p I_p
$$

The problem also has final boundary condition (at $t_f$) as voltage and current at maximum power $V_{mpp}$ and $I_{mpp}$. Hamiltonian equation, $H$ is formulated as follows:

$$
H = 0.5 u^2 + \lambda_1 \left( \frac{V_i}{L} \frac{u}{L} x_2 \right) + \lambda_2 \left( \frac{u}{C_s} x_1 + \frac{V_B x_2}{C_s r_B} \right)
$$

The condition at final time is $\psi_1 = x_1 = k_1$, where $k_1$ is determined from maximum power calculation model, therefore maximization is

$$
\phi = V_p x_1 + k_1
$$

From equ. (5) then the complete performance index become:

$$
\min J = V_p x_1 + k_1 + \frac{1}{2} \int_{t_0}^{t_f} u^2 \, dt
$$

The necessary condition for reaching maximum $P_p$ in $t_0$ to $t_f$ time are costate equation that contain objective function. The costate are:

$$
\begin{align*}
    \dot{\lambda}_1 &= -H_1 = -\frac{\lambda_2 u}{C_s} \\
    \dot{\lambda}_2 &= -H_2 = \lambda_1 \frac{u}{L} + \frac{\lambda_1}{C_s r_B}
\end{align*}
$$
The final condition at $t_f$ are:
\[
\lambda_1(t_f) = \phi_1 = -V_p \\
\lambda_2(t_f) = \phi_2 = 0
\]  
(9)

The sufficient condition for optimal control is satisfied if derivation of the Hamiltonian $H$ to $u$ is 0,
\[
\frac{dH}{du} = u - \lambda_1 \frac{x_2}{L} + \lambda_2 \frac{x_1}{C_s} = 0
\]  
(10)

\[
u = \lambda_1 \frac{x_2}{L} - \lambda_2 \frac{x_1}{C_s}
\]  
(11)

The chosen solvers for BVP is collocation method and Newton single shooting and then in this research are called classical method. The algorithm efficiency is measured as time complexity or $O$ (big oh). For detail about it can be seen in [2] and [16].

3. Numerical Experiments

The research material is optimal control of solar photovoltaic power generation system as proposed in Mahout and Boitier (2003). In this experiment the system parameters are as in table 1, 2, and 3.

Table 1. Photovoltaic panel parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cell in parallel, $n_p$</td>
<td>1</td>
</tr>
<tr>
<td>Number of series cell, $n_s$</td>
<td>36</td>
</tr>
<tr>
<td>Short circuit current at 25C, $I_{sc}$</td>
<td>3,8 A</td>
</tr>
<tr>
<td>Open circuit voltage, $V_{oc}$</td>
<td>21.06 Volt</td>
</tr>
<tr>
<td>Diode quality factor, $A$</td>
<td>1,2</td>
</tr>
<tr>
<td>Boltzman const., $k$</td>
<td>$1,38 \times 10^{-23}$</td>
</tr>
<tr>
<td>Temperature, $T$</td>
<td>25 ºC</td>
</tr>
<tr>
<td>Electron charge, $q$</td>
<td>$1,6x10^{-19}$ C</td>
</tr>
</tbody>
</table>

Table 2. DC-DC converter parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inductance, $L$</td>
<td>2,2 mH</td>
</tr>
<tr>
<td>Capacitance, $C_s$</td>
<td>30 µF</td>
</tr>
</tbody>
</table>

Table 3. Battery parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Resistance, $r_B$</td>
<td>0,5 Ω</td>
</tr>
<tr>
<td>Battery voltage, $V_B$</td>
<td>24 Volt</td>
</tr>
</tbody>
</table>

Numerical experiments is used an application software MATLAB® and Wavelab packet that can be downloaded freely from Stanford University website.

In this research we use Wavelab850, operating system Windows XP, and personal computer with Intel Pentium 4 processor and RAM 384 MB.

The global research or experiment flow is shown in figure

4. Result and Discussion

Experiment with a change for maximum power from irradiance of 0.5 Sun to 1 sun is conducted for all method. From maximum power at initial condition $t_0$ is found:

\[
P_{mpp} = 29,7576 \text{ Watt};
\]
\[
V_{mpp} = 16,8055 \text{ Volt};
\]
\[
I_{mpp} = 1,7707 \text{ Ampere}.
\]

Final condition at $t_f$ is defined as:

\[
P_{mpp} = 60,4582 \text{ Watt};
\]

Figure 2. Research flow
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Malacca, Malaysia, June 2-3, 2009

\[ V_{mp} = 17,1111 \text{ Volt; } \]
\[ I_{mp} = 3,5333 \text{ Amp. } \]

From initial and final condition can be determined

\[ x_1(t_0) = 1,7707 \text{ A and } \]
\[ x_1(t_f) = 3,5333 \text{ A } \]
\[ x_2(t_0) = V_B = 24 \text{ Volt (same as battery voltage). } \]

The result of trajectory of state variable i.e. PV current (\(x_1\)) and output voltage (\(x_2\)) is shown in figure 3 and 4.

The results show that all method regardless the execution time finally can reach good maximum power at \(t_f\) as 60.4586 Watt and 48.6039 Watt for battery. But the different is computation time. Table 4 shows the result summary of measured execution time in Big O basis.

<table>
<thead>
<tr>
<th>Method</th>
<th>Time complexity</th>
</tr>
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<tbody>
<tr>
<td>Classic</td>
<td>(O(n^{1.4854}))</td>
</tr>
<tr>
<td>Haarlet</td>
<td>(O(n^{1.2617}))</td>
</tr>
<tr>
<td>Daubechies</td>
<td>(O(n^{1.2390}))</td>
</tr>
<tr>
<td>Coiflet</td>
<td>(O(n^{1.2606}))</td>
</tr>
</tbody>
</table>

It can be seen that all three wavelet adaptation is better in computational time. They also better form Newton based solver as shown in figure 5. IVP stand for Newton initial value problem, colloc is collocation method without adaptation.

Measurement result is related with adaptive discretization. The classical method has equally space discretization. But adaptive discretization are not uniform as shown by figure 6 for example of the Haar wavelet discretization.
In classical method the number of discretization grid is $2^5 + 1 = 257$. But Haar wavelet can reduce grid number to 103 grid only, for Coiflet 100 and even Daubechies dispose 184 grid and left only 73 in 4 iteration. It can be summarized that the more reduce grid the quickest computation.

5. Summary

Optimal control of solar power generation can be solved through BVP with Hamiltonian and produce optimal trajectory as expected.

In the case of power maximization all method produce the same result of 60.4586 W. It can be seen that adaptation do not reduce optimal result

Solving optimal control with wavelet approach can increase the computation efficiency and get quickest result significantly

6. References


CIM2009

2nd International Conference on Control, Instrumentation and Mechatronic Engineering
2\textsuperscript{nd}-3\textsuperscript{rd} June, 2009

Renaissance Hotel
Melaka, Malaysia

Program & Abstracts

Organized by

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Universiti Teknologi Malaysia (UTM) is moving ahead to be a World Class University and taking earnestly in enhancing the development and utilization of inventions and design. With the challenges ahead, more quality research projects and breakthrough technologies that can be commercialized being carried out, as emphasized by the government.

Conferences have been one of the platforms for the researchers to promote their new technologies and findings to the public and industries. UTM has a large pool of technology already developed, readily available in various fields which the industry can tap. A true smart partnership will hopefully develop between UTM and potential industries or investors. In fact, we aim to achieve closer collaboration with the industries and nurturing the culture of knowledge sharing to the publics. I personally would like to extend our invitation to all of you for further discussion and to pursue an effective collaboration in our future growth.

Lastly but not least, I would like to thank everyone who has made CIM 2009 a successful event.

Sincerely,
Zaini Ujang
Vice Chancellor Universiti Teknologi Malaysia
The future development of industries in Malaysia focuses on areas such as Advance Manufacturing, ICT and its applications, Robotics and Control & Instrumentation. In this instance, Faculty of Electrical Engineering is also joining the many organization and industries in taking part to become a global player. Showcasing and commercialization of the university's R & D products, innovations and findings are under way. This is necessary in order for the faculty and university to move into marketable goods and services, thus increasing the university earnings and image.

I would like to take this opportunity to wish success to all the researchers who take part in this conference.

Sincerely,
Ahmad Darus
Dean of Faculty of Electrical Engineering, UTM
Message by the Organizing Committee Chair

Department of Control & Instrumentation Engineering (CIED) and Department of Mechatronics & Robotics Engineering (MER) of Faculty Electrical Engineering are happy to organize the 2nd Conference on Control, Instrumentation & Mecatronics Engineering (CIM 2009). All this would not have been possible without your constant support. So, first we would like to say thank you. Thank you for your ever growing interest in the field of Control, Instrumentation & Mecatronics (CIM) Engineering. The broad view of the conference remains the same as before: to examine the future of CIM Engineering.

The conference brings together researchers, academics, industry practitioners and students in order to share ideas, expand engineering knowledge, and introduce well-established techniques. The idea of the conference stemmed from the need of passionate CIM engineers to unite with others to promote the fields; the desire to attract bright minds to research CIM engineering; and the demand for bringing people together to discuss how theory is implemented. Therefore, our priority is the promotion and development of CIM engineering as a new discipline.

Offering students, as well as teachers and professionals, a conference that combines purely scientific considerations with the industrial practical applications in the effervescent field of CIM engineering is what distinguishes us from other conferences. The conference is synonymous to new knowledge and personal enrichment. It is an occasion for passionate presenters to communicate their thoughts and works to an equally passionate audience.

The conference has traditionally included corporate, academic and paper presentations.

The organizing team would like to welcome you to CIM 2009, hoping we enjoy it all together until the very last minute.

Sincerely,
Ruzairi Abdul Rahim
On behalf of the CIM 2009 Team.
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Conference Venue Floor Plan

Function Rooms Level 7
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Bunga Melati Room, Bunga Teratai Room,
Bunga Dahlias Room & Bunga Mawar Room.

Function Rooms Level 2
Bendahara Room
Conference Schedules

Tuesday, 2nd June 2009
08:00-12:00  Registration
09:00-09:30  Coffee/Tea break
09:30-11:00  Keynote Lecture
11:15-12:55  Technical Session I
  Advanced Control Theory & Applications I (TS1-I)
  Mechatronics I (TS2-I)
  Intelligent Control Systems I (TS4-I)
  Power System Control I (TS8-I)
  Tomography I (TS10-I)
12:55-14:00  Lunch break
14:00-16:00  Technical Session II
  Mechatronics II (TS2-II)
  Robotics I (TS3-II)
  Intelligent Control Systems II (TS4-II)
  Power System Control II (TS8-II)
  Tomography II (TS10-II)
16:00-16:10  Coffee/Tea break
20:00-22:30  Conference Dinner at Hotel Pool Side Level 9

Wednesday, 3rd June 2009
08:30-10:30  Technical Session III
  Advanced Control Theory & Applications II (TS1-III)
  Mechatronics III (TS2-III)
  Intelligent Control Systems III (TS4-III)
  Industrial Control & Applications I (TS6-III)
  Biomedical I (TS9-III)
10:30-10:50  Coffee/Tea break
10:50-12:50  Technical Session IV
  Advanced Control Theory & Applications III (TS1-IV)
  Process Control (TS5-IV)
  Industrial Control & Applications II (TS6-IV)
  Smart Sensors & MEMS (TS7-IV)
  Biomedical II (TS9-IV)
12:50-14:00  Lunch break
14:00-16:00  Technical Session V
  Advanced Control Theory & Applications IV (TS1-V)
  Mechatronics IV (TS2-V)
  Robotics II (TS3-V)
  Power System Control III (TS8-V)
  Tomography III (TS10-V)

16:00  Coffee/Tea break
Technical Sessions Information

List of Technical Sessions:
1. Advanced Control Theory & Applications (TS1)
2. Mechatronics (TS2)
3. Robotics (TS3)
4. Intelligent Control Systems (TS4)
5. Process Control (TS5)
6. Industrial Control & Applications (TS6)
7. Smart Sensors & MEMS (TS7)
8. Power System Control (TS8)
9. Biomedical (TS9)
10. Tomography (TS10)

These technical sessions will be conducted at five function rooms:
1) Ballroom 2        2) Bunga Melati      3) Bunga Teratai
4) Bunga Dahlia   5) Bunga Mawar

Refer to the table on page 14 for overview of technical sessions and rooms.

Information for Session Chairs

The chairs of each session are expected to arrive at the Technical Session room 5 minutes before the session begins, and check the attendance of the paper presenters in the session.
The session chair is required to obtain the brief biographies of the presenters for the sessions.
Session chairs are advised to keep all presentations according to the scheduled time.

Information for Paper Presenters

1. Each presenter is allocated 20 minutes. The presentation time is limited to 15 and 5 minutes for discussion.
2. All presenters are requested to report to the session chair 5 minutes before session begins.
3. All presenters are requested to give a brief biography to their session chair before the session start.
4. All paper presenters must fill up the CIM2009 copyright form. The form can be obtained from the secretariat during the conference.
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<th>Date &amp; Time</th>
<th>BALLROOM 2</th>
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<th>BUNGA DAHLIA</th>
<th>BUNGA MAWAR</th>
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<tr>
<td>Tuesday 2nd June 2009 10:00-11:00</td>
<td>Keynote Chair: Johari H. S Osman</td>
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<td>Tuesday 2nd June 2009 11:15-12:55</td>
<td>TS10-I Tomography I Chair: (5)</td>
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<td>Tuesday 2nd June 2009 14:00-16:00</td>
<td>TS10-II Tomography II Chair: (6)</td>
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<td>TS9-III Biomedical I Chair: (6)</td>
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<td>Wednesday 3rd June 2009 10:50-12:50</td>
<td>TS9-IV Biomedical II Chair: (6)</td>
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<td>Wednesday 3rd June 2009 14:00-16:00</td>
<td>TS1-V Advanced Control Theory &amp; Appl. IV Chair: (5)</td>
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Technical Sessions Schedules

Tuesday, 2nd June 2009

Keynote Lecture 10:00-11:00 Room: Ballroom 2
“Research and Development of Unmanned Helicopter Systems”
Keynote Speaker: Professor Ben M. Chen, Singapore
Chair: Professor Dr. Johari Halim Shah Osman, Malaysia

Technical Session TS1-I 11:15-12:55 Room: Bunga Melati
Advanced Control Theory & Applications I
Chair: Samsul Bahari Mohd Noor
Co-Chair: Mohamad Noh Ahmad

11:15-11:35 22 “Intelligent Reference Learning Techniques for Pitch Control of an Aircraft”
P S Khuntia and Debjani Mitra
Durgapur Institute of Advanced Technology and Management & Indian School of Mines, INDIA

11:35-11:55 30 “Validating Inter-Arrival Time and Inter-Departure Time for Traffic Intersection using Simulation”
Azura Che Soh, Mohammad Hamiruce Marhaban & Marzuki Khalid, Rubiyah Yusuf
Universiti Putra Malaysia & Universiti Teknologi Malaysia

11:55-12:15 59 “Design of Sliding Mode Controller for a Bench-top Helicopter”
Amir Hossein Zaeri and Samsul Bahari Mohd Noor
Universiti Putra Malaysia

12:15-12:35 62 “Design of QFT Controller for a Bench-top Helicopter”
Universiti Putra Malaysia

12:35-12:55 69 “Integral sliding mode control design for high speed tilting trains”
Hairi Zamzuri, Argyrios Zolotas and Roger Goodall
Universiti Teknologi Malaysia & Loughborough University

Technical Session TS2-I 11:15-12:55 Room: Bunga Teratai
Mechatronics I
Chair: Wahyudi
Co-Chair: Rosbi Mamat

11:15-11:35 43 “Vibration Control of a Flexible Thin Plate Using Active Force Control”
Ali Reza Tavakolpour, Intan Z. Mat Darus, Musa Mailah
Universiti Teknologi Malaysia

B. M. Albaker and N. A. Rahim
University of Malaya

Muhammad Faheezal Ismail and Yahaya Md. Sam
Universiti Kuala Lumpur Malaysia France Institute & Universiti Teknologi Malaysia

S.A. Nyabundi, G. Qi, Y Hamam, J. Munda
Tshwane University of Technology, South Africa

12:35-12:55 124 “Robust PID Anti-swing Gantry Crane Control: Tuning by PSO”
Mahmud Iwan Solihin and Wahyudi
International Islamic University Malaysia
Technical Session TS4-I 11:15-12:55
Intelligent Control Systems I
Chair: Intan Z. Mat Darus
Co-Chair: Shahrum Shah

11:15-11:35 40 "Neural Network-based Identification of a Flexible Plate Structure for Active Vibration Control"
Ali Reza Tavakolpour, Intan Z. Mat Darus, Musa Mailah
Universiti Teknologi Malaysia

11:35-11:55 53 "Neuro-Genetic Controller For Gas-Turbine Dynamics Nonlinear System"
Marwan A. Ali, Mat Sakim, H.A.
Universiti Sains Malaysia

S. Mohammad Reza Loghmanian, Robiah Ahmad and Hishamuddin Jamaluddin
Universiti Teknologi Malaysia

12:15-12:35 66 "Fuzzy Logic Control of a Magnetic Ball System"
Kashif and S. S. Abdullah
Universiti Teknologi Malaysia

12:35-12:55 164 "Corner Detection for Clothes Handling using Image Processing"
Khairul Salleh, Hiroaki Seki, Yoshitsugu Kamiya, Masatoshi Hikizu
Universiti Tenaga Nasional Malaysia & Kanazawa University, Japan

Technical Session TS8-I 11:15-12:55
Power System Control I
Chair: Mohd Fuad Rahmat
Co-Chair: Zuwairie Ibrahim

11:15-11:35 25 "Sustainable Household Energy Saving Plan"
Ooi Chia Ai, Baharuddin M.Y
Universiti Malaysia Perlis

11:35-11:55 51 "PID-Cascade for HVAC System Control"
Raad Z. Homod, T. M. I. Mahlia, Haider A. F. Mohamed
University of Malaya & University of Nottingham Malaysia Campus

11:55-12:15 52 "Rejection of Sensor Deterioration, Noise, Disturbance and Plant Parameters Variation in HVAC System"
Raad Z. Homod, T. M. I. Mahlia, Haider A. F. Mohamed
University of Malaya & University of Nottingham Malaysia Campus

12:15-12:35 65 "New Control Technique for Three Phase Voltage Sags and Swells Compensation"
Rosli Omar and Nasrudin Abd Rahim
Universiti Teknikal Malaysia Malaka & University Of Malaya

12:35-12:55 70 "Wavelet Based Optimal Control Solution for Nonlinear Systems"
Sasongko Pramono Hadi, Soedjatmiko, Warindi
Gadjah Mada University & University of Mataram, Indonesia
Technical Session TS10-I 11:15-12:55  Room: Ballroom 2

Tomography I
Chair: Hafiz Fazalul Rahiman
Co-Chair: Sallehuddin Ibrahim

11:15-11:35  ID3  “New Sensor Design for Capacitance Tomography”
Ruzairi Abdul Rahim, Chan Kok Seong, Mohd. Hafiz Fazalul Rahiman, Jaysuman Puspanathan, Yvette Shaan-Li Susiapan
Universiti Teknologi Malaysia & Universiti Malaysia Perlis

Jaysuman Puspanathan, Ruzairi Abdul Rahim, Zulkarnay Zakaria, Mohd Hafiz Fazalul Rahiman, Yvette Shaan-Li Susiapan
Universiti Teknologi Malaysia & Universiti Malaysia Perlis

Jaysuman Puspanathan, Ruzairi Abdul Rahim, Zulkarnay Zakaria, Mohd Hafiz Fazalul RahimaN, Yvette Shaan-Li Susiapan
Universiti Teknologi Malaysia & Universiti Malaysia Perlis

12:15-12:35  ID6  “Digital Signal Processor in Optical Tomography System”
Siti Zarina Mohd. Muji, Ruzairi Abdul Rahim, Chiam Kok Thiam
University Tun Hussein Onn Malaysia & Universiti Teknologi Malaysia

12:35-12:55  ID7  “Low Cost ECT Sensor Electrodes Design”
Ruzairi Abdul Rahim, Tee Zhen Cong, Jaysuman Puspanathan, Yvette Shaan-Li Susiapan
Universiti Teknologi Malaysia

Technical Session TS2-II 14:00-16:00  Room: Bunga Teratai

Mechatronics II
Chair: Sallehuddin Ibrahim
Co-Chair: Zaharuddin Mohamed

14:00-14:20  139  “Advanced mechatronic system for in-line automated optical inspection of metal parts”
Tomasz Giesko, Adam Mazurkiewicz, Andrzej Zbrowski
Institute for Sustainable Technologies – National Research Institute, Poland

14:20-14:40  150  “Friction Compensation In Dc-Motor Drive System Using Adaptive Neuro Fuzzy Inference System (Anfis)”
Tijani, I.B., Wahyudi M. and Talib H.H.
International Islamic University Malaysia

14:40-15:00  155  “Two-parameter Compensator Design for Point-to-point (PTP) Positioning System Using Algebraic Method”
Furtojo, R. Akmeiawati and Wahyudi
Indonesia Islamic University & International Islamic University Malaysia

15:00-15:20  174  “Velocity Control of EHSS by Using ANFIS Controller”
Veeda Aghaei Hesari, Mahdi Aliyari SHoorehdeli, Mohammad Teshnehlab
The Islamic Azad University Science and Research, Iran

15:20-15:40  175  “Suppressing Noise and Vibrations in the Disk Brake System by a Robust Active Control Method”
S.M Hashemi-Dekordi, M. Mailah, A.R. Abu-Bakar
Universiti Teknologi Malaysia

15:40-16:00  181  “Hybrid Control of Flexible Link Manipulator by using Neural Networks”
Veser Namazikhab, Mahdi Aliyari SHoorehdeli, Mohammad Teshnehlab
The Islamic Azad University Science and Research, Iran
Technical Session TS3-II 14:00-16:00
Robotics I
Chair: Khairul Salleh
Co-Chair: Salinda Buyamin

14:00-14:20 24 "Stereo Vision Based Robotic Bin Picking System For Agile Manufacturing"
A.S. Fathinul-Syahir, H. Desa, S.M. Juhairi Aziz
Universiti Malaysia Perlis

14:20-14:40 57 "Analytical Solution of Torch Orientation for Straight Arc Welding Trajectory"
Chua B. L.
Universiti Malaysia Sabah

14:40-15:00 107 "Design, Simulation and Fabrication of UNIMAS Robot Hand-1 (URH-1)"
Shahrol Mohamaddan, T.W.J. David, Noor Hisyam Noor Mohamed1, Aidil Azli Alias, Syed Tarmizi Syed Shazali, Siti Nor Ain Musa1, Ervina Junaidi, Mohamad Shahril Osman and Kasumawati Lias
Universiti Malaysia Sarawak

15:00-15:20 111 "Efficient Weighted Block Iterative Method for Robot Path Planning Using Harmonic Functions"
Azali Saudy and Jumat Sulaiman
Universiti Malaysia Sabah

15:20-15:40 131 "Multilayer Infrared-Based Face Identification System for Security Robot Vision"
Khairul Hamimah Abas and Osamu Ono
Universiti Teknologi Malaysia & Meiji University, Japan

15:40-16:00 185 "Real-Time Control in Deformable Object Tracing by Robot"
Khairul Salleh, Hiroaki Seki, Yoshitsugu Kamiya, Masatoshi Hikizu
Universiti Tenaga Nasional Malaysia & Kanazawa University, Japan

Technical Session TS4-II 14:00-16:00
Intelligent Control Systems II
Chair: Dayang Norhayati A. Jawawi
Co-Chair: Zuwairie Ibrahim

14:00-14:20 135 "DNA Computing Readout Approaches: A Review"
Muhammad Faiz Mohamed Saaid, Zuwairie Ibrahim, Shahdan Sudin, Marzuki Khalid, Nor Haniza Sarmin
Universiti Teknologi Malaysia

14:20-14:40 136 "DNA Sequence Optimization: A Methodology Overview"
Noor Khatifah Khalid, Zuwairie Ibrahim, Tri Basuki Kurniawan, Shahdan Sudin, and Marzuki Khalid
Universiti Teknologi Malaysia

14:40-15:00 130 "RAM-Network-based Type-2 Fuzzy-Neural Controller for Mobile Robot"
Siti Nurmaini, Siti Zaiton Mohd Hashim, Dayang Norhayati A. Jawawi
Universiti Teknologi Malaysia

15:00-15:20 142 "Real Time Fuzzy Regression Analysis with Fuzzy Data"
Azizul Azhar Ramli, Junzo Watada and Witold Pedrycz
Waseda University, Japan & Polish Academy of Sciences, Poland

15:20-15:40 160 "Improving Particle Swarm Optimization Convergence with Spread and Momentum Factors"
Idris Abd Latiff and M. O. Tokhi
University of Sheffield, United Kingdom

15:40-16:00 109 "A PID-Like ANFIS Controller Trained by PSO Technique to Control Nonlinear Systems"
O. F. Lutfy, S. B. Mohd Noor, M. H. Marhaban and K. A. Abbas
Universiti Putra Malaysia

Room: Bunga Melati

Room: Bunga Mawar
Technical Session  TS8-II  14:00-16:00

Power System Control II
Chair: Rosli Omar
Co-Chair: Shahdan Sudin

14:00-14:20  77  "Voltage Sag Compensation Using Dynamic Voltage Restorer (DVR)"
             Rosli Omar and Nasrudin Abd Rahim
             Universiti Teknikal Malaysia Melaka & University Of Malaya

14:20-14:40  85  "Enhanced PLL Topology For Distorted Grid Supplies"
             Karthik Ramasubramanian and Mahesh Kumar Mishra
             National Institute of Technology & Indian Institute of Technology, INDIA

14:40-15:00  89  "Wavelet-Galerkin Based Method For The Solution Of Solar Power Generation
             Optimization Under Fast Changing Weather Condition"
             Soedjatmiko and Warindi
             Gadjah Mada University & University of Mataram, Indonesia

15:00-15:20  97  "DSP-based Multifunction Numerical Relay for Protection of Small Industrial
             Power System"
             P. K. Shadhu Khan, Md. Rifat Shahriar and Md. Nurul Islam
             Chittagong University of Engineering &Technology & International Islamic
             University Chittagon, BANGLADESH

             System at Reliance Industries Ltd. (RIL), PTA Plant, Patalganga plant, INDIA”
             Keyur. Vora
             Reliance Industries Limited, INDIA

15:40-16:00  123 "Performance Improvement of DPDC SCADA System Using Hard Real-Time
             OS"
             C. M. I. Hussain, M. Alam and A. M. Azad
             BRAC University, BANGLADESH

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Technical Session  TS10-II  14:00-16:00

Tomography II
Chair: Sallehudin Ibrahim
Co-Chair: Zulkarnay Zakaria

14:00-14:20  ID8  "A Comparative Study on Ultrasonic Transceiver Sensing Array for Bubbly
              Gas Hold Ups"
              M.H. Fazalul Rahiman, R. Abdul Rahim, S. Yaacob, Z. Zakaria and M.R.
              Manan
              Universiti Malaysia Perlis & Universiti Teknologi Malaysia

14:20-14:40  ID9  "Real-Time Image Reconstruction Using Object Oriented Programming
              Method"
              M.H. Fazalul Rahiman, R. Abdul Rahim and Z. Zakaria
              Universiti Malaysia Perlis & Universiti Teknologi Malaysia

14:40-15:00  ID10 "The Ultrasonic Tomography Front-End Hardware Design for Two-Phase High
              Acoustic Impedance Mixtures"
              M.H. Fazalul Rahiman, R. Abdul Rahim, S. Yaacob, Z. Zakaria and N.M. Nor
              Ayob
              Universiti Malaysia Perlis & Universiti Teknologi Malaysia

15:00-15:20  ID11 "Ultrasonic Tomography; The Applications Of 32 Transceivers Technique In
              Two Phase Flow Imaging"
              Universiti Malaysia Perlis & Universiti Teknologi Malaysia
Technical Session TS4-III 08:30-10:30
Intelligent Control Systems III
Chair: Shahrum Shah Abdullah
Co-Chair: Mohd Ariffanan Mohd Basri

8:30-8:50  165  "Object Representation Using Length for Classification by Artificial Neural Network"
Faieza Hanum Yahaya, Nooritawati Md. Tahir, Mahanijah Md. Kamal, Hafizah Husain, Mohd Dani Baba
Universiti Kebangsaan Malaysia

8:50-9:10  167  "Enhancement of Auto Image Zooming using Fuzzy Set Theory"
Irraivan Elamvazuthi, Muntaj Begam and Mohamed Khan Aftab Ahmed Khan
Universiti Teknologi PETRONAS & Universiti Industri Selangor, Malaysia

9:10-9:30  178  "Face Detection Using Radial Basis Function Neural Networks With Fixed Spread Value"
Khairul Azha A. Aziz and Shahrum Shah Abdullah
Universiti Teknikal Malaysia Melaka & Universiti Teknologi Malaysia

9:30-9:50  LP14  "Optimization of Neural Network Model Structures for Valve Stiction Modeling"
H. Zabiri and N. Mazuki
Universiti Teknologi PETRONAS, Malaysia

9:50-10:10  LP15  "Robustness Study on NARXSP-based Stiction Model"
H. Zabiri and N. Mazuki
Universiti Teknologi PETRONAS, Malaysia

10:10-10:30  190  "Development of Metamodelling Tool for Optimization of Control System Using MATLAB"
Nor Hana Mamat, Shahrum Shah Abdullah, Mohamad Afi Kasno
TATi University College & Universiti Teknologi Malaysia

10:30-10:50  LP17  "Automated MR Brain Image Segmentation and Classification Using Neuro Fuzzy"
Mohd Ariffanan Mohd Basri, Mohd Fauzi Othman and Shahdan Sudin
Universiti Teknologi Malaysia

Technical Session TS6-III 08:30-10:30
Industrial Control & Applications I
Chair Norma Alias
Co-Chair: Norkharziana Mohd Nayan

8:30-8:50  72  "Application of Digital Signal Controller to Study the Effects of Brushless DC Motor Performance Using Various Types of PWM Switching Schemes"
Norkharziana Mohd Nayan, Syafrudin Masri, Muhammad Nasiruddin Mahyuddin, Norshafinash Saudin
Universiti Sains Malaysia

8:50-9:10  73  "A Simplified Design of a 3-Phase Inverter: An Approach of Using the Microcontroller to Drives Brushless DC Motor"
Norkharziana Mohd Nayan, Syafrudin Masri, Muhammad Nasiruddin Mahyuddin, Norshafinash Saudin
Universiti Sains Malaysia

9:10-9:30  75  "High Performance Computing of Thermal Control Simulation for Multilayer Full-chip Design"
Norma Alias, Noriza Satam, Zarith Safiza Abd. Ghaffar and Mohamed Othman
Universiti Teknologi Malaysia& Universiti Putra Malaysia

9:30-9:50  116  "Mapping of FPGA's Programming Language to the Ladder Logic Program Elements"
Razali Jidin and Syed Zahidul Islam
Univ. Tenaga Nasional, Malaysia
Technical Session TS9-III  08:30-10:30  
Room: Ballroom 2
Biomedical I
Chair: Sallehudin Ibrahim
Co-Chair: Zuwairie Ibrahim

8:30-8:50  68  "Parameter Optimization of FLC for FES-assisted indoor rowing exercise: Comparison between PSO and GA"
Z. Hussain, M. O. Tokhi and R. Jailani
University of Sheffield, United Kingdom

8:50-9:10  74  "Brain Machine Interface Design using Minimum Electrodes for Recognition of Imagined Hand Movements"
Hema C.R., Paulraj M.P., Sazali Yaacob, Abdul Hamid Adom and Nagarajan R.
Universiti Malaysia Perlis

9:10-9:30  79  "Behaviour of the Hand-Arm Postural Tremor Model in Simulation and Experimental Study"
Azizan As'arry, Mohd Zarhamdy Md. Zain, Musa Mailah, Mohamed Hussein, Mohd Yunus Abdullah
Universiti Teknologi Malaysia

9:30-9:50  129  "Signed LMS based Adaptive Filtering to ECG Analysis: Noise Cancellation and Arrhythmia Detection"
Mohammad Zia-Ur-Rahman, Rafi Ahamed Shaik, D V Rama Koti Reddy and Ibrahim Khan
Andhra University, Indian Institute of Technology & Indian Institute of Information Technology, India

9:50-10:10  166  "Classification of Heart Valve Disease"
Mohd Zubir Suboh, M.Y. Mashor, A.R. Mohd Saad, M.S. Mohamed, Khor B.T.
Universiti Malaysia Perlis, Universiti Sains Malaysia & Hospital Tuanku Fauziah

10:10-10:30  197  "Feature Extraction and Translation of Electroencephalogram Signal in Human for Noninvasive Brain-Computer Interface"
Siti Zuraimi Salleh, Norlaili Mat Safri and Siti Hajar Aminah Ali
Universiti Teknologi Malaysia & Universiti Tun Hussein Onn Malaysia

Technical Session TS1-IV  10:50-12:50  
Room: Bunga Melati
Advanced Control Theory & Applications III
Chair: Yakaya Md Sam
Co-Chair: Shahdan Sudin

10:50-11:10  173  "Identification of Hybrid Systems by Fuzzy Piecewise Affine Models"
Masood Askari, Haider A. F. Mohamed, M. Moghavvemi, S. S. Yang
University of Malaya & University of Nottingham Malaysia Campus

11:10-11:30  176  "Implementation of Model Predictive Control on Unstable Systems"
Masood Askari, Haider A. F. Mohamed, M. Moghavvemi, S. S. Yang
University of Malaya & University of Nottingham Malaysia Campus

11:30-11:50  LP06  "Adaptive PI Controller of a Spark Ignition Engine"
Mohd Isa Othman, Hazliina Selamat & Ahmad Jais Alimin
Universiti Teknologi Malaysia & Universiti Tun Hussein Onn Malaysia
Power System Control (TS8)

[25] Sustainable Household Energy Saving Plan
Ooi Chia Ai, Baharuddin M.Y
Universiti Malaysia Perlis

Demand Side Management (DSM) encompasses the entire range of activities such as planning, implementation and monitoring that influence the pattern and magnitude of a utility's load. DSM is a method of containing and reducing the overall cost of energy. For the power system, the demand side starts beyond the electric meter and consists of energy appliances and surrounding energy related installations. The energy demand is determined by the energy users' need for energy-related services such as light or a specific indoor climate [1].

[51] PID-Cascade for HVAC System Control
Raad Z. Homod, T. M. I. Mahlia, Haider A. F. Mohamed
University of Malaya & University of Nottingham Malaysia Campus

The primitive controller used in the early version for the HVAC, like the on-off (Bang-Bang) controller, which is inefficient, inaccurate, instable, and high-level mechanical wear. While the PID, compensator, cascade controllers overcoming to these disadvantages but when the offset response (inaccurate), occur; the power consumption will increase. In order to acquire better performance in the central air-conditioning system, the PID-cascade control was studied through comparing the traditional PID, industrial PID (Ziegler-Nichols tuning) and compensator controllers in simulation and experiments. The output of system was predicted through indoor, outdoor disturbance, at last based on the mathematical model of air-conditioning space, the simulations have found that PID- cascade controller has the capability of self-studying and self-adapting and obtain faster response and better performance.

[52] Rejection of Sensor Deterioration, Noise, Disturbance and Plant Parameters Variation in HVAC System
Raad Z. Homod, T. M. I. Mahlia, Haider A. F. Mohamed
University of Malaya & University of Nottingham Malaysia Campus

The main objective of this paper is to reject faults tolerant like sensor deterioration, noise, disturbance and depreciation of the plant in Heating, Ventilating and Air Conditioning (HVAC) System. a fault tolerant controller system (FTCS) strategy for temperature control of air-conditioning system has been proposed. The setpoint response controller in the FTCS is designed in terms of insusceptible with noise, failure sensor, disturbance and parameter variation with optimal performance specification. According to the system operation requirement for faults rejection, a closed-loop for rejecting fault signals is configured. It is found that the setpoint response, the disturbance rejection, the noise rejection, the robust, rejection of failure sensor and the performance of the designed FTCS are better than conventional PID. Therefore the residual signal can now be used to monitor faults in the system while the proposed method ensures correctness of operation.

[65] New Control Technique for Three Phase Voltage Sags and Swells Compensation
Roslil Omar and Nasrudin Abd Rahim
Universiti Teknikal Malaysia Melaka & University Of Malaya

Custom power using power electronics is a new technology developed to provide protection from power quality related disturbances. Dynamic Voltage Restorer (DVR) is useful for compensating voltage quality problems that are due to voltage sag and swell. The control for DVR based on dpc algorithm is discussed. The proposed control scheme is simple to design. Simulations were carried out using the MATLAB/SIMULINK. Simulation results proved the capability of the DVR in mitigating voltage sags and swells in a distribution system.

[70] Wavelet Based Optimal Control Solution for Nonlinear Systems
Sasongko Pramono Hadi, Soedjatmiko, Warindi
Gadjah Mada University & University of Mataram, Indonesia
The main objective of the research is to show the advantages of wavelet based method from conventional ones to solve a nonlinear problem in a photovoltaic solar power generation. This nonlinearity comes from a case of limited power of solar radiation and expensive cost of solar panel, therefore maximization of absorbed power is become important. To solve the problem, the system state space approach is used. The optimal control problem is transformed and reduced to a boundary value problem using Hamiltonian equation derivation. To increase computation speed, a wavelet analysis is used as time discretization adaptation on numerical solver that uses time discretization basis. The wavelet is employed as analysis tool at each discretization level, start from coarse to finer discretization. The temporary grid result at present level is then used for determining the next level discretization. The final results of determining maximum power, prove that optimal control scheme can be used to solve control problem of solar power generation. The computation results also show that computation speed increases significantly by employing wavelet adaptation on the conventional solver without decreasing its accuracy.

[77] Voltage Sag Compensation Using Dynamic Voltage Restorer (DVR)
Roslí Omar and Nasrudin Abd Rahim
Universiti Teknikal Malaysia Melaka & University Of Malaya

The Dynamic Voltage Restorer (DVR) as a means of series compensation for mitigating the effect of voltage sags has become established as a preferred approach for improving power quality at sensitive load locations. In this paper the operation of a DVR is presented. The power circuit of a DVR together with the control techniques used for compensation voltage sag is discussed. DVR is considered to be the most efficient and effective solution. Its appeal includes lower cost, smaller size and its dynamic response to the disturbance. This research described DVR principles and voltage restoration methods for balanced and/or unbalanced voltage sags in a low distribution system. Simulation results were presented to illustrate and understand the performances of DVR under voltage sags/swells conditions. The simulation results are presented to verify the performance of DVR in load for voltage sag compensation.

[85] Enhanced PLL Topology For Distorted Grid Supplies
Karthik Ramasubramanian and Mahesh Kumar Mishra
National Institute of Technology & Indian Institute of Technology, INDIA

Phase angle of grid voltage is an important source of information for grid connected power systems. In this work to extract the exact phase angle, an improved algorithm has been proposed for realizing a 3-phase Synchronous Reference Frame(SRF) phase locked loop(PLL) under distorted grid conditions by incorporating a Linear phase FIR filter coupled with an adaptive PI controller. The performance of the PLL has been verified for unbalance, frequency variation, phase jump, dc offset voltage swell and sag. The output of the PLL has negligible distortion and the stability and dynamics of the system response is also enhanced. Thus the PLL is robust to non-ideal gird conditions and can be used in Custom power devices and ac/dc converters.

Soedjatmiko and Warindi
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The objective of the research is to solve a nonlinear optimization problem as found in photovoltaic power generation under fast changing weather temperature and radiation. Such problem needs a very quick solver, otherwise the output power will not be optimal and the efficiency decreases. Although classical solution approaches have been established, but most of them are not suitable for rapidly changing environmental conditions. Thus, it is necessary to find an alternative method that will be able to give a better optimal result using nonlinear model. To solve such problem, the system state space approach is used. The optimization problem is transformed into Wavelet-Galerkin solution space and expressed in terms of wavelet system of coordinates. Then by using wavelet transformation matrix and proper rescaling followed by progressive iteration, the MPP problem can be solved in short time. The