10th Eco-Energy and Materials Science and Engineering Symposium


On December 5-8, 2012
Sunee grand hotel,
Ubon-ratchathani

Organized by

Co-organized by
PREFACE:
Message from the President of
Rajamangala University of Technology Thanyaburi

Rajamangala University of Technology Thanyaburi (RMUTT), in conjunction with Kyoto University, is pleased to host the 10th Eco-Energy and Materials Science and Engineering Symposium (10th EMSES). This international conference is not only giving an opportunity for Thai and foreign researchers to present and discuss their research works and update their expertise but also to initially stimulate the development of research works on eco-energy and materials science and engineering. Our program consists of six research tasks: (1) Energy Technology, (2) Environmental and Social Impact, (3) Nanotechnology and Materials Science, (4) Energy Economics and Management, (5) New Energy Technology and (6) Nuclear Technology.

I would like to take this opportunity to express our sincere gratitude to our two distinguished Plenary Speakers for kindly accepting our invitation. I deeply appreciate of the very strong support given by Kyoto University. Thanks to the tireless works of the Organizing Committee, the Technical Program Committee, the invited speakers and paper and poster contributors, and excellent program been assembled to cover a broad spectrum of interesting topic.

We warmly welcome you to the 10th EMSES on December 5-8, 2012, Ubon Ratchathani, Thailand.

Numyoot SONGTHANAPITAK, Ph.D.
President of Rajamangala University of Technology Thanyaburi and Conference Chairman of 10th EMSES 2012
PREFACE:
Message from the Director of
Institute of Advanced Energy, Kyoto University

It is my great pleasure to have the 10th Eco-Energy and Materials Science and Engineering Symposium (EMSES) with Rajamangala University of Technology Thanyaburi (RMUTT) under the long-term collaboration between RMUTT and Kyoto University. The 1st EMSES was held in 2001 in Thailand and the symposium has been expanded in its scientific contents as well as the academic network. I believe that the 10th EMSES gives a good opportunity to all participants to exchange their knowledge and idea to realize eco-friendly energy system in society. I would like to express my welcome to all participants and sincere thanks to the 10th EMSES organizing committee and all supporting organizations to make us having this symposium.
I hope that the symposium will be successful and lead to further progress in energy science and technology and also in friendships of participants.

Yukio Ogata, Ph.D.
Director of Institute of Advanced Energy, Kyoto University
PREFACE:
Message from the Former Dean of
Graduate School of Energy Science, Kyoto University
Program Leader,
Global COE “Energy Science in the Age of Global Warming”

I want to express my hearty welcome to all participants of Eco-Energy and Materials Science and Engineering Symposium (10th EMSES). This symposium is aiming the realization of importance of energy and materials technology through the academic, science and technology network among the world communities. The symposium gives an opportunity for researchers to discuss their research works and also to initially stimulate the development of research works on eco-energy and materials science and engineering. Once the cooperation among researchers has been created, the further cooperation work will be developed.

I would like also extend my sincere thanks to all who made the meeting possible, including the 10th EMSES organizers, the SEE forum committee members, and the Japanese Government, JSPS, for their kind support. I am looking forward to seeing you in Ubon Ratchathani, Thailand.

Professor Takeshi YAO, Ph.D.
Former Dean of Graduate School of Energy Science, Kyoto University
and Program Leader, Global COE “Energy Science in the Age of Global Warming”
Message from the Chairperson of 10th EMSES Organizing Committee

Rajamangala University of Technology Thanyaburi (RMUTT), in conjunction with Kyoto University, is pleased to host the 10th Eco-Energy and Materials Science and Engineering Symposium (10thEMSES).

RMUTT has a major mission on encouraging and supporting all areas of research. One of the key reasons is to assist in developing capability in science and technology in order to cope with recent rapid change in this field. We have jointly set up an academic symposium on the 10thEMSES with the perception on the significance of exchanging knowledge and research experiences between researcher in the field of energy, materials technology and environmental science. This symposium is not only giving an opportunity for Thai and foreign researcher to present and discussion their research works and update their expertise but also to initially stimulate the development of research works on eco-energy and materials science and engineering. Once the cooperation among researchers has been created, the closer future cooperation incorporate with joint-research works will be developed. Thus, to support the aforesaid role, the symposium working committee would like to invite you to participate in this academic symposium.

I would like to express our sincere thanks to the organizing committee, participants and contributors for your kind corporation to this symposium. I wish this symposium proceeding will be a useful reference for future scientific research development.

Sommai PIVSA-ART, Ph.D.
Dean of Faculty of Engineering, RMUTT
Director of CoE on Sustainable Energy System (Thai-Japan)
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### Conference Program of 10th Eco-Energy and Materials Science and Engineering

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**Time**

| 07:00-09:00 am| Registration |       |
| 09:00-09:40 am| Opening Ceremony at Taptim Siam 4 Hall | Assoc. Prof. Dr. Numyoot Songthanapitak, President of RMUTT, Thailand and Chairperson of 10th EMSES conference |
| 09:45-10:45 am| Keynote Speaker I: Japan Power Generation Mix and Energy Security after Fukushima Nuclear Accident, presented by Prof. Dr. Kiyoshi Yoshikawa, Vice President of Kyoto University, Japan Co-Chairperson of 10th EMSES conference | Coffee break |
| 10:45-11:00 am| Keynote Speaker II: Vertical Motions in Greater Bangkok Area after the 2004 Sumatra-Andaman Earthquake from GPS Observations and Its Prediction based on the Geophysical Modelling, presented by Prof. Dr. Chalermschon Satirapod, Chulalongkorn University, Thailand |       |
| 12:00-01:30 am| Lunch at Taptim Siam 5 Hall |       |

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<td>Dr. Sorapong Pavisupree</td>
<td>Asst. Prof. Dr. Warunee Arnyawiyiyanan</td>
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# Conference Program of 10th Eco-Energy and Materials Science and Engineering

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<td>Assoc. Prof. Dr. Yuji</td>
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<td>Dr. Narongchai O-Charoen</td>
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<td>Co-Chair</td>
<td>Dr. Winai Chanpeng</td>
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Prof. Dr. Takeshi Yao, Leader of GCOE Program/Professor, Graduate School of Energy Science, Kyoto University
Voltage Control by DQ Frame Technique of SVPWM AC-DC Converter

N. Moungkhum and W. Subsingha
Department of Electrical Engineering, Faculty of Engineering, Rajamangala University of Technology Thanyaburi, Klong 6, Thanyaburi, Pathumthani 12110
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Abstract—This paper presents a simulation model of Space vector Pulse Width Modulation (SVPWM) Rectifier using MATLAB/Simulink. Its ability is to stabilize an output voltage of 500 Vdc from a 3 phase 300V system using a decoupling feed-forward control method by dq frame technique. The model is tested due to a variation of ±10% of rated input voltage. From the simulation model, it can use for implementation into a real-time control system by Digital Signal Processing Board (such as DS1104). Together, it also can be designed into a real circuit easily and effectively. The experimental results show that the SVPWM Rectifier which is presented in this paper has an adequate performance which can be applied widely.

Keywords—About DQ Frame, SVPWM Rectifier, Decoupling Control

1. INTRODUCTION

Nowadays, the pulse width modulation technique which is applied in AC-DC converter has a lot of interesting aspects. Such as a stabilization of DC output voltage, less harmonics in output voltage and its better power factor. These could help in supporting and improving the power system quality. This paper presents a voltage control of such ac-dc converter utilized by the space vector pulse width modulation (SVPWM) technique and a novel d-q frame approach. Thus, the converter will transform an unstable input voltage from 3 phase AC system into a stabilized DC output voltage in a short time response.

2. MATHEMATICAL MODEL OF SVPWM AC-DC CONVERTER

The SVPWM AC-DC converter presents in this paper can be seen in Figure 1, which is composed of a balanced R-L series impedance in arbitrary of 3 phase input system. In the converter circuit, it uses of 6 IGBTs as switching devices, resistance at load side and also use capacitor as low-pass filtering.

All of 6 electronic switches (IGBT) in Figure 1 has been controlled by control signals utilized by SVPWM approach. However, the SVPWM pattern is generated using a novel d-q frame as described following.

Considering the 3 phase sinusoidal input voltage of the converter as a stationary reference frame,

\[ V_{sa}(t) = V_m \cos(\omega t) \]  \hspace{1cm} (1)

\[ V_{sb}(t) = V_m \cos(\omega t - \frac{\pi}{3}) \]  \hspace{1cm} (2)

\[ V_{sc}(t) = V_m \cos(\omega t + \frac{2\pi}{3}) \]  \hspace{1cm} (3)

which \( V_m \) is maximum voltage of the arbitrary 3 phase system.

From the circuit in figure 1, equations of inductive voltage in each phase and capacitive current can be written as follows.

\[ L \frac{dv_a}{dt} = V_{sa} - f_a V_{dc} \]  \hspace{1cm} (4)

\[ L \frac{dv_b}{dt} = V_{sb} - f_b V_{dc} \]  \hspace{1cm} (5)

\[ L \frac{dv_c}{dt} = V_{sc} - f_c V_{dc} \]  \hspace{1cm} (6)

\[ C \frac{di_a}{dt} = f_a i_{sa} + f_b i_{sb} + f_c i_{sc} - I_{load} \]  \hspace{1cm} (7)

\( f_a, f_b, f_c \) Represent as switching function of the AC-DC converter, which is

\[ f_a = \frac{(2S_a - S_b - S_c)}{3} \]  \hspace{1cm} (8)

\[ f_b = \frac{(2S_b - S_a - S_c)}{3} \]  \hspace{1cm} (9)

\[ f_c = \frac{(2S_c - S_a - S_b)}{3} \]  \hspace{1cm} (10)
The relationship of abc to dq reference frame

\[ S_a, S_b, S_c \] is also represented as control signals that use to control in arbitrary phase of such converter. Each of control signals is significant as "1" or "0". This means that, if \( S_a = '1' \) the upper switch in phase A is "ON" (the lower switch in phase A is OFF). Otherwise, when \( S_a = '0' \) the upper switch in phase A is "OFF" and lower switch will be ON.

Therefore, these control signals that utilized in arbitrary 3 phase can be transformed into a two axis vector, which called as synchronous d-q reference frame. In which, it can be written as follows

\[
\begin{bmatrix}
X_d \\
X_q
\end{bmatrix} = \frac{1}{3} \begin{bmatrix}
\cos(\omega t - \frac{\pi}{3}) & \cos(\omega t + \frac{\pi}{3}) \\
-\sin(\omega t - \frac{\pi}{3}) & -\sin(\omega t + \frac{\pi}{3})
\end{bmatrix} \begin{bmatrix}
S_a \\
S_b
\end{bmatrix}
\] (11)

As described above, output voltage of the AC-DC converter can be mentioned into totally 8 switching states (refer to 2^3 bit). These eight vectors are called the basic space vectors and are denoted by \( V_0 - V_7 \). This is due to the transformation of the arbitrary 3 phase control state into D-Q frame as shown in Figure 2. The voltage vector of the converter can be illustrated as shown in Figure 3. Mean by that, Table 1 shows the relationship between each switching state in any phase correspond to an arbitrary voltage vector and the occurrence of output phase voltage, respectively.

However, there are only six active voltage vectors (V1-V6) that will provide an output voltage value. These voltage vectors are corresponding to each others in a hexagonal shape as seen in Figure 3. Meanwhile, there are two of zero vector (V0 and V7) that lied on the origin and provide no output voltage value.

The objective of SVPWM technique is to approximate the reference voltage vector \( V_{ref} \) in an arbitrary sector as illustrated in Figure 3 by using eight switching patterns. One simple method of approximation is to generate the average output of the inverter in a small period \( T \) respect \( V_{ref} \) in such period. Mean by that, it utilize all six switching states together with an additional two more states in order to calculate the time period (T1, T2, T0).

**Table 1. Switching patterns and output vectors**

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<th>No. of Vectors</th>
<th>Switching state</th>
<th>Output phase voltage</th>
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<td>V_{ref}</td>
<td>V_{ac}</td>
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<tr>
<td>1 1 0</td>
<td>V_{dc}</td>
<td>V_{dc}</td>
</tr>
<tr>
<td>1 1 1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The time period (T1, T2, T0), it can be written as follows

\[
T_0 = \frac{T - T_1 - T_2}{2}
\] (12)
\[
T_1 = \frac{2\sqrt{3}}{\pi} MT \sin(\frac{\pi}{3} - \alpha)
\] (13)
\[
T_2 = \frac{2\sqrt{3}}{\pi} MT \sin(\alpha)
\] (14)
\[
T_i = \frac{1}{f_s}
\] (15)
\[
M = \frac{V^*}{V_{slew}} = \frac{V^*}{\frac{2}{\pi} V_{dc}}
\] (16)

By given \( M \) as modulation ratio, \( f_s \) as switching frequency.

**3. VOLTAGE FEED-FORWARD DECOUPLING CONCEPT**

This article is to control output voltage using the principle voltage feed-forward decoupling for optimized to provide more efficiency. It can be written as follows equation (17)-(29).

\[
L \frac{\text{d}v_t}{\text{d}t} = v_t + \omega L i_{eq} - f_s V_{dc}
\] (17)
\[ L \frac{d i_d}{dt} = V_{sq} - \omega L i_q - f_q V_{dc} \]  
(18)

\[ C \frac{d v_d}{dt} = \frac{3}{2} (f_d i_d + f_q i_q) - I_{load} \]  
(19)

When determine 

\( i_{sd} \) and \( i_{sq} \) are current values in \( d-q \) axis

\( f_d \) and \( f_q \) are switching functions in \( d-q \) axis

\( V_{sd} \) and \( V_{sq} \) are voltage values in \( d-q \) axis

\( \Omega \) is Radian/sec.

Which,

\[ V_{sd} = V_m \]  
(20)

\[ V_{sq} = 0 \]  
(21)

Replace equation (20) and (21) into (17) and (18), it can be written as follows

\[ L \frac{d i_d}{dt} = V_m + \omega L i_q - f_d V_{dc} \]  
(22)

\[ L \frac{d i_d}{dt} = -\omega L i_q - f_q V_{dc} \]  
(23)

\[ V_d = f_d V_{dc} \]  
(24)

\[ V_q = f_q V_{dc} \]  
(25)

\[ L \frac{d v_d}{dt} = V_m + \omega L i_q - V_d \]  
(26)

\[ L \frac{d v_d}{dt} = -\omega L i_q - V_q \]  
(27)

\[ v_d^* = V_{sd} - (K_p + \frac{K_i}{S})(i_d^* - i_d) + \omega L i_q \]  
(28)

\[ v_q^* = V_{sq} - (K_p + \frac{K_i}{S})(i_q^* - i_q) + \omega L i_q \]  
(29)

From equation (28) and equation (29), it can be built a block diagram as

![Fig.4 Voltage Feed-Forward decoupling block diagram](image)

**Fig.4 Voltage Feed-Forward decoupling block diagram**

### 4. SIMULATION AND RESULTS

This article is controlling and analysis the stability of SVPWM AC-DC Converter output voltage using a decoupling feed-forward control method by \( d-q \) frame technique. The model of SVPWM AC-DC Converter circuits has built using Matlab/Simulink as shown in Figure-5.

![Fig.5 Block diagram by Matlab/Simulink](image)

The simulation parameter of SVPWM AC-DC Converter as described in Table-2.

<table>
<thead>
<tr>
<th>Rs=1e5 Ω</th>
<th>Cs=1e-3 F</th>
<th>R load=100kΩ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tf(s)=1e-6</td>
<td>Tl(s)=2e-6</td>
<td>C = 1.5e-3</td>
</tr>
</tbody>
</table>

![Fig.5 Block diagram by Matlab/Simulink](image)

**Table-2. Switching patterns and output vectors**

![Fig.6 Voltage input on step load](image)

**Fig.6 Voltage input on step load**

![Fig.7 Voltage output on step load](image)

**Fig.7 Voltage output on step load**
5. CONCLUSION

The experimental result of SVPWM AC-DC Converter circuits can control output voltage using d-q frame technique in a good response when load changes as shown in Figure-7. Another result shows that the output voltage can be kept stable when the input voltage is varied from 300 V down to 270 V at a constant load. By the researcher’s opinion the times response of SVPWM AC-DC Converter output voltage have to be improved in further.

Nevertheless the simulation model that prescribe above can be modify to use as implementation model which use with DSP board such as DS1104 in order to generate the real time control signal. This can control a real time converter, which apply in any application such as wind generator and so on as shown Figure 10. Which the researcher was successfully developed as shown Figure 11. The may be a significant aspect for some power electronics application in renewable energy area.

6. REFERENCES LIST


