

DOCTORAL DISSERTATION

Modeling of a Hybrid Fuel Cell Vehicle Based on Physical Models of the Different Different Components in Matlab/Simulink Components in Matlab/Simulink

(Maximum 4 lines) (Style:Thesisname)

Mr. Thomas Goodspeed (Style:Thesisname)



(Style: First page) A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTORAL IN ELECTRICAL POWER ENGINEERING

THE SIRINDHORN INTERNATIONAL THAI-GERMAN GRADUATE SCHOOL OF ENGINEERING

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Author

|  |  |
| --- | --- |
| Name | Mr. XYZ (All texts in this table use Style: Author) |
| Title | Modeling of a Hybrid Fuel Cell Vehicle Based on Physical Models of the Different Components in Matlab/Simulink |
| Major Field | Electrical Engineering |
| Advisor | Professor Dr. –Ing. AProfessor Dr. –Ing. BProfessor Dr. –Ing. C |
| Academic Year | 2007 |

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Nisai Fuengwarodsakul

Abstract

(Style: Abstract). The abstract should have less than 200 wordsAs the resources of crude oil decrease more and more, alternative propulsion systems have to be found. Fuel cell systems offer clean and efficient energy production and are currently under intensive development by several manufacturers for both stationary and mobile applications. The viability, efficiency and robustness of this technology depend on understanding, predicting and controlling the unique transient behavior of the fuel cell systems. Furthermore, simulations support the investigation and development of specific control strategies.

Within this thesis a global model of a fuel cell vehicle based on physical models of the different components has to be developed. This model is based on a pure hydrogen fuel cell system powered by a 80 kW direct hydrogen PEMFC. Some of needed model are already available and have to be adjusted for the implementation into a global model. Missing component models have to be developed within this thesis. Two different models of fuel cell stacks are available at Institut für Krafahrwesen Aachen (IKA). These models have to be compared and the use for the global model has to be verified. The transient behaviour captured in the model should include flow characteristics, inertia dynamics, lumped volume manifold filling dynamics, reactant pressure and reactor temperatures.

Keyword: Fuel cell, Hybrid, Battery, Supercapacitor, transient behavior, control strategy

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Nomenclature

*Af* Front area [m2] (Style:Nomenclature)

*C* Capacitance Capacitance Capacitance Capacitance Capacitance Capacitance Capacitance Capacitance Capacitance

*CD*Aero dynamic drag coefficient

*c1* Constant 1 used in activation loss

*c2* Constant 2 used in concentration loss

*c3* Constant 3 used in concentration loss

*g* gravity

*HD* Hybridization degree

*i* Current [Amp]

*Rint* Internal resistance [Ω]

*RL* Dielectric resistance [Ω]

*I* Current

# Introduction

This template is designed to help TGGS students in writing their thesis in the correct format. The automatic formatting including automatic reference of figures, tables, equations and references will make editing the thesis fast and simple. The students can save plenty of time in editing and formatting. The automatic feature of this template ensures the accuracy and correctness of the table of contents and the references.

The following chapters explain how to use this template in a correct and efficient way. Please bear in mind that the template will be only helpful and efficient when the users know how to use it in correct ways, otherwise the template may cause trouble, more work and headache instead.

Fdsfsdfjsdk aklsdfasd fd asdklfjasdlfj

# How to use this template

## Text style

In this template, every text must be defined with text styles given in the following table:

Table .1 Used styles in this template shown in the quick style gallery

|  |  |
| --- | --- |
| **Style** | **Used for/in** |
| Abstract | In page: Abstract |
| Acknowledgement | In page: Acknowledgement |
| Author | In page: Author |
| Biography | In page: Biography |
| Caption | For all captions, e.g. figures tables and equations. |
| Emphasis | Any text that you would like to emphasize with italic fonts  |
| First page | In first page for description and copyright texts.  |
| Heading 0 | Unnumbered chapter for example, abstract, bibliography etc.  |
| Heading 1 | Numbered chapter for example chapter 1, chapter2 etc. |
| Heading 2 | Numbered section |
| Heading 3 | Numbered subsection |
| Nomenclature | Nomenclature |
| Normal | Text bodies in chapters |
| Strong | Any text that you would like to emphasize with bold fonts |
| Title | In first page for Title and Author’s name |
| List paragraph | Any lists |
| Blibiography | In page: Bibliograpy |
| TOC1 | In page: Table of content |
| TOC2 | In page: Table of content |
| TOC3 | In page: Table of content |
| Table of figure | List of figure, List of table |
|  |

For correct and consistent formatting, please try to use only the predefined styles in . The overview of the styles applied in the document structure is illustrated in Chapter 3. By applying a correct style, the table of content will be automatically updated according to the applied text style.

1. Heading 0 appears as unnumbered chapter
2. Heading 1 appears as numbered chapter
3. Heading 2 appears as section
4. Heading 3 appears as subsection

For a clear and well-structured writing, the template allows only 3 levels of heading.

### Formatting symbol

In order to have a clear view of the formatting control, the formatting symbols must be shown by clicking at the pi-symbol in **Home:Paragraph** box.

Figure .1 How to show the formatting symbol

### Starting a new page

In certain situation, the author would like to force a new page start. This can be done by clicking at Page Break in **Insert:Pages** box.

Figure .2 How to start a new page

### Changing the text style

To change the text style, just mark the text and then clicking at the quick style gallery in **Home:Style** box**.**

Figure .3 How to change the text style

## First page

Note that the position of the texts on the first page is fixed at the defined position. The user just simply type in the box with the given style. Never delete the section break in this page.

## Page number in header

The page number in the header is configured for printing on one side as default. If the user would like to print in double side format, just double-click at the header. Then the design tool for header and footer will appear as shown in Figure 2.4. Tick the option Different odd and even page. Then the page number of the even page and the odd page will be on the opposite side.

Figure .4 Options for double-side printing

## Important notes

1. Never delete the section break, otherwise the system of page reference will collapse. There are two section breaks. The first one is at the end of the first page. The second one is at the beginning of Chapter 1.

2. In general please use only given text styles in order to keep your document consistent. The self-defined styles could be used only when it is really necessary.

3. For every text styles, e.g. headings, after pressing ENTER for a line break the text style for the new paragraph will return to Normal.

# Heading 1

## Heading 2

Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal

### Heading 3

Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal

### Heading 3

Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal Normal

Figure .1 Caption (The caption of figure is on the bottom of the associated figure)

Table .1 Caption (The caption of table is on the top of the associated table)

|  |  |  |
| --- | --- | --- |
| Normal | Normal | Normal |
| Normal | Normal | Normal |
| Normal | Normal | Normal |

Remark: For continuous tables, the caption of the continuous table should be a cross-reference not a caption. This can be done by selecting the cross-reference and ticking for the entire caption. The example is as follows,

Table 3.1 Caption (The caption of table is on the top of the associated table) (cont.)

An example of list paragraph is shown as follows:

1. List paragraph
2. List paragraph
3. List paragraph
4. Sdklfjsadlfasdjkl
5. Asdkl;fasldfasdlfl
6. Lsdfadfjasdfj
7. Asdklfasdlfj

34tdfgsdfgdfg

## Heading 2

### Heading 3

### Heading 3

# Automatic links of objects

## Inserting figure

1. Copy an existing caption of figure and paste it to a line.

2. Place the cursor in front of the caption

3. Then insert picture by selecting picture in **Insert:Illustration.**

 Figure 4.1 Inserting picture

4. The figure may be shown incompletely. The wrapping control must be with the option Top and Bottom should be selected as shown in Figure 4.2. Then also select More layout option.

Figure 4.2 Wrapping control for a picture

5. Set the horizontal alignment and the vertical alignment and all options as shown in Figure 4.3. Please note that the option of advanced layout must be readjusted after whenever the picture has been resized. The anchor symbol must be on the line of the caption. In this way the figure is associated with the caption all the time.

Figure 4.3 Configuring advanced layout

## Inserting table

1. The user just draws a table. Then insert a caption at the top of the table, as shown in the table below.

Table .1 The caption of table is on the top of the associated table)

|  |  |  |
| --- | --- | --- |
| Normal | Normal | Normal |
| Normal | Normal | Normal |
| Normal | Normal | Normal |

2. The caption can be copied from the existing one.

## Inserting equation

Actually, the equations are placed in a table as shown below. The equation caption is placed in the right column. To use it just copy the equation table and place it anywhere you want. For the equations with no caption, the caption can be simply deleted.

|  |  |
| --- | --- |
|  | (.) |
|  | (.) |
|  | (.) |

After the equations have been placed correctly, then the border of the table must be set to no border as shown below:

|  |  |
| --- | --- |
|  | (.) |
|  | (.) |
|  |  |

For manually inserting a caption of equation, the label must be excluded from the caption by selecting the option as shown below. Then copy the caption and place it into the right column of the equation table.

Figure 4.4 Caption of equation

## Inserting cross reference

1. To insert the cross-reference of heading, figure, table and, just select Cross-Reference in **Insert:Links** box. Then the cross-reference window will be shown as . Select the desired reference and then click insert.

Figure 4.5 Inserting cross-reference

2. For equation, the option must be selected as shown below. Then, the user should type the word “Equation” manually before the cross-reference e.g. Equation **Error! Reference source not found.**

Figure .6 Options for referring equation

## Citation and bibliography

### Inserting citation and adding new source

To insert citation, the user must add new sources or reference which can be books, papers etc., by clicking Insert Citation in **Reference:Citation&Bibliograpy** box. Note that the used style is GOST-Name Sort. The user may add new source or reference by clicking at Add New Source as shown in .

Figure .7 Options for referring equation

Figure .8 Adding new source

The user can insert citation by clicking at the existing citation in . After that the citation will appear, for example, as.

### Generating bibliography list

For generating the bibliography list, the user should go to the chapter bibliography and then clicking Bibliography in Reference:Citations&Bibliography box and choose Insert Bibliography as shown in .

Figure .9 Generating bibliography list

## Updating of all references

To update all of automatic links and references, just use Ctrl-A(select all) and then press F9. Then, you will be asked to select an option as shown in . For a complete update, please select “Update entire table” for all tables.

Figure .10 Options when updating automatic tables

Bibliography

**Fuengwarodsakul Nisai** Battery management [Book]. - Bangkok : Elsevier, 2022.

**Fuengwarodsakul Nisai** Corrration of sdfdfkdkd [Journal] // Advanture works monthly. - 2012. - pp. 15-62.

**Hunter** asfasdf [Journal]. - asdfasdf : asdf, asdfa. - asdf : Vol. asdf. - asdf.

Biography

The author can describe him/herself here.

Appendix

**Amendments**

|  |  |
| --- | --- |
| Document version | Amendments |
| Template\_Thesis\_Version\_November\_2013 | - Adding “A Thesis” in the first page |
| Template\_Thesis\_Version\_December\_2013 | - Change the style of bibliography reference from ISO690 to GOST-Name Sort. |
| Template\_Thesis\_Version\_April\_2014 | - Change the left margin to 1.5 inch and the right margin to 1 inch. - Install an IEEE citation style by copying the file IEEE\_Reference.XSL to the path of Microsoft office’s bibliography style (example: C:\Program Files\Microsoft Office\Office12\Bibliography\Style). Using the IEEE citation style the citation will be as follows, [1][2][3]. |
| Template\_Thesis\_Version\_December\_2014 | - Adjust the page margin (left 1.0 to 1.5 inch in the preface section)- Adjust the format of the table of content by reducing the tab length. - Adjust the format of the table of figure and table by changing the hanging tab  |