

SP1-JTI-CS-2013-02

Power cable modelling for WIPS
electromechanical chain

Project reference:
SGO-02-077 - MultyCaB - 632458

Deliverable 4
ASSESSMENT REPORT
November 2015

PUBLIC

Subject: Deliverable 4

Document type: Public

Prepared by: UPC, Universitat Politècnica de Catalunya
MCIA Research Center



This page is left in blank intentionally



1.	INTRODUCTION	5
2.	CONVERTER OUTPUT VOLTAGES	6
3	CABLE MODEL	8
3.1	SINGLE CELL MODEL	8
3.2	MULTI CELL MODEL.....	9
3.3	THREE-CONDUCTORS' SCREENED CABLE WITH 5 CELLS.....	9
4	MAT MODEL	12
	CONCLUSIONS	14
	REFERENCES	15



Introduction



1. Introduction

Several promising technologies are being explored and developed by Clean Sky, one of which is the optimization of electrical Wing Ice Protection System (**WIPS**), which provides electro-thermal protection protects against the build-up of ice on structures of the aircraft.

The electro thermal WIPS protection system embeds electro-thermal heater mats into the surface to be protected, for instance, the inner surface of a designated area of the aircraft wing.

Power converters based on IGBT technology have typical modulation frequencies in the range of 2-20 kHz with typical switching times of 50 ns which induce fast voltage changes (dv/dt) which excite the parasitic elements of the cables and mats, so to simulate the behavior of the cable model a high frequency model of the system is required.

Fig. 1.1 shows a diagram of the elements constituting the WIPS.

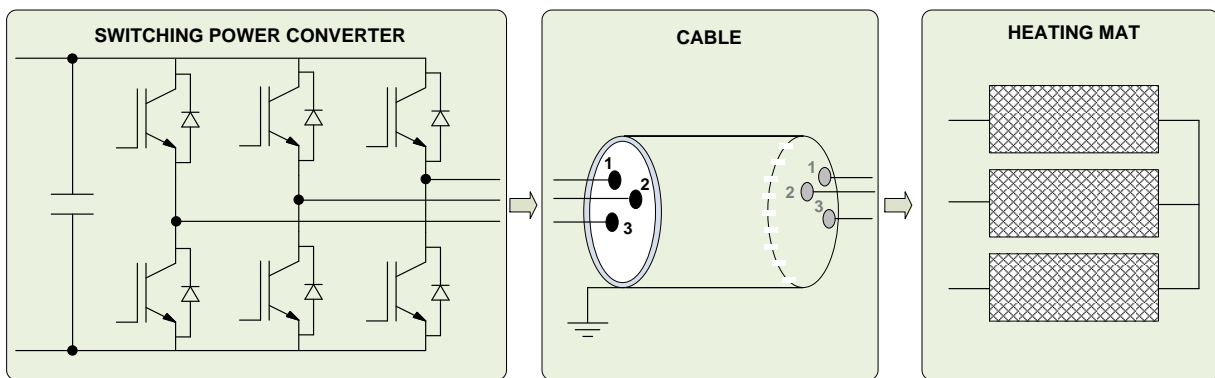


Fig. 1.1. Converter, cable and heating mat.

To perform a realistic simulation of such system three elements are required:

- **Output response of the power converter**, that is, voltage versus time waveforms for all phases.
- A **high-frequency model of the cable system** dealt with in the range 40 Hz-30 MHz.
- A **basic model of the mat system**.

This deliverable (D4) establishes the data and elements required to perform a realistic high-frequency model of the cable for the WIPS system.

The model of a **three-conductor screened cable** is evaluated in D4.

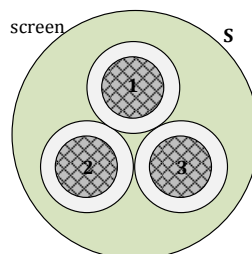


Fig. 1.2. Three-conductor screened cable.

2. Converter output voltages

The output voltages of a three-phase switching converter are used as stimulus of the cable model. Fig. 2.1 shows the phase-to-neutral voltages of the switching power converter dealt with, which are used to test the transient response of the cable model.

- DC Bus: 537,4 VDC
- Switching frequency: 5 KHz
- Main AC harmonic: 400Hz
- Dead time: 20 us
- Rise time: 0 us
- Fall time: 5 us

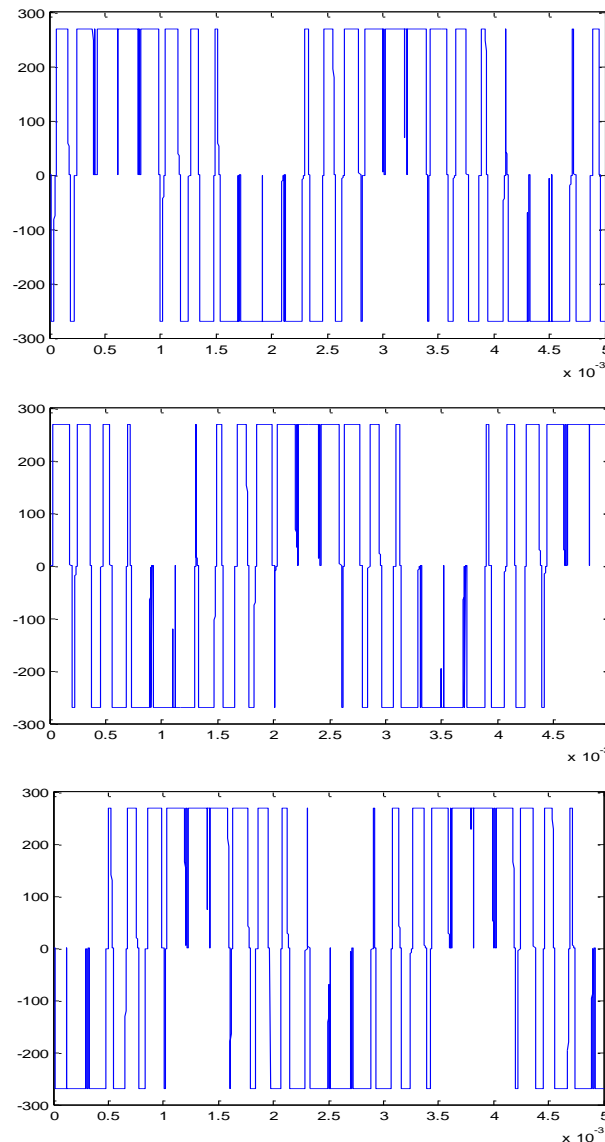


Fig. 2.1. Phase-to-neutral signals of the three-phase switching power converter.



MULTYCAB

November 2015 Deliverable 4

Document	Deliverable 4
Facilities	-
Revision	Revised
Date	November 2015

Cable model



3 Cable model

In this section the results provided by the solver developed in this project are validated against the results provided by the commercial solver EMTPWorks® 2015a(3.1.0).

To this end we checked the accuracy of the high-frequency cells model shown in Fig. 3.1 and Table 3.1 against the EMTP code when using the stimulus of the three-phase switching converter shown in Fig. 2.1.

3.1 Single cell model

Fig. 3.1 and Table 3.1 show the high-frequency single cell model dealt with.

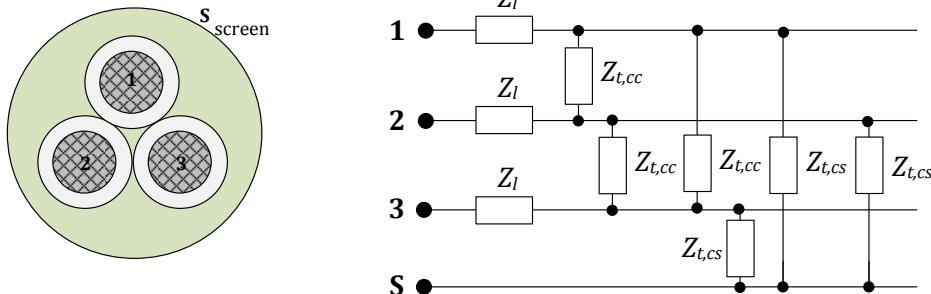


Fig. 3.1. Single cell model for a three-conductor screened cable

Table 3.1. Impedances included in the cell model

Impedance type	Ladder model
Longitudinal impedance (Z_l)	
Transversal impedance between conductors ($Z_{t,cc}$)	
Transversal impedance between conductor and screen ($Z_{t,cs}$), only for screened cables	

3.2 Multi cell model

The multi cell model of any cable configuration with n cells is obtained by connecting in series or cascade as shown in Fig. 3.2. It is worth noting that all cells are identical, therefore they all have the same configuration and values of their components (R , L and C).

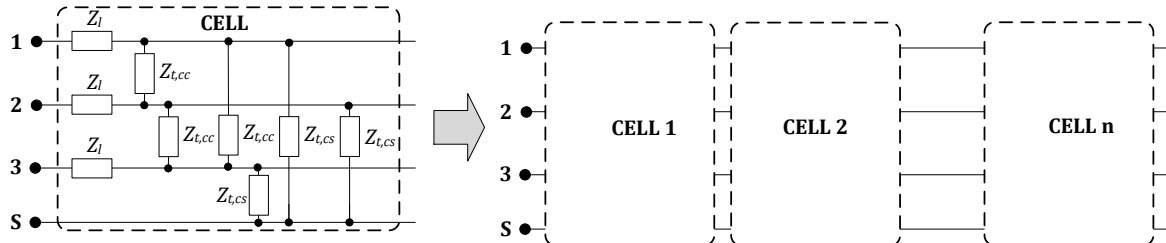


Fig. 3.2. Multi cell model for a three-conductor screened cable

3.3 Three-conductors' screened cable with 5 cells

The accuracy of the code programmed in this project was validated against the results provided by the EMTWorks® software assuming five cells in series or cascade, as shown in Fig. 3.2. Comparative results provided by these two programs are summarized in Figs. 3.3 and 3.4, which show the great similarity between the output values of both solvers.

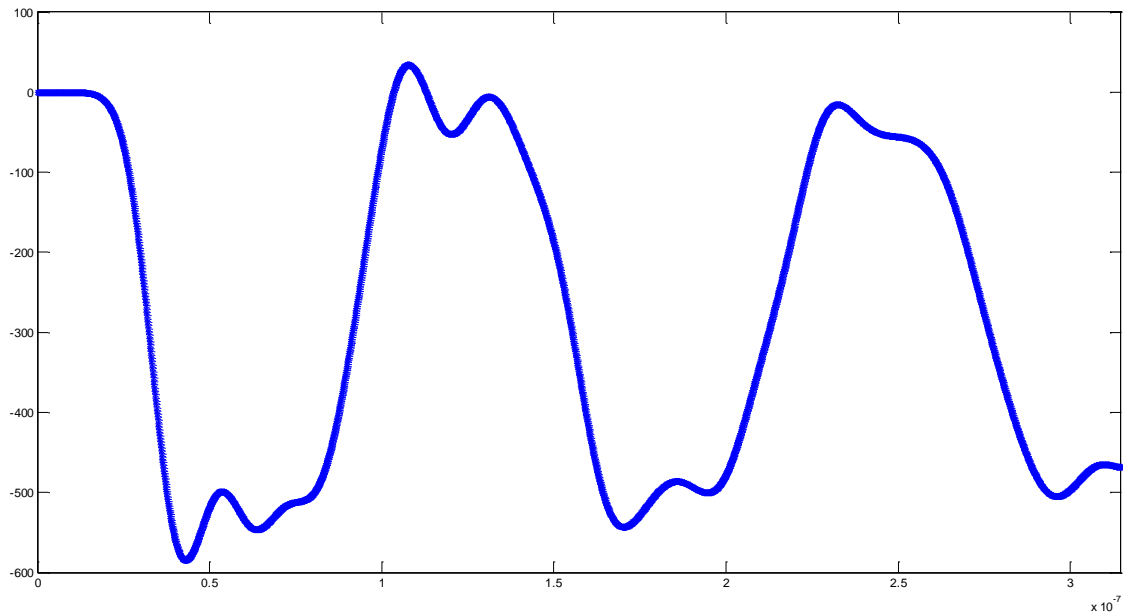


Fig 3.3. Output voltage provided by the Matlab code (red) and by the EMTP simulation (blue)

Document	Deliverable 4
Facilities	-
Revision	Revised
Date	November 2015

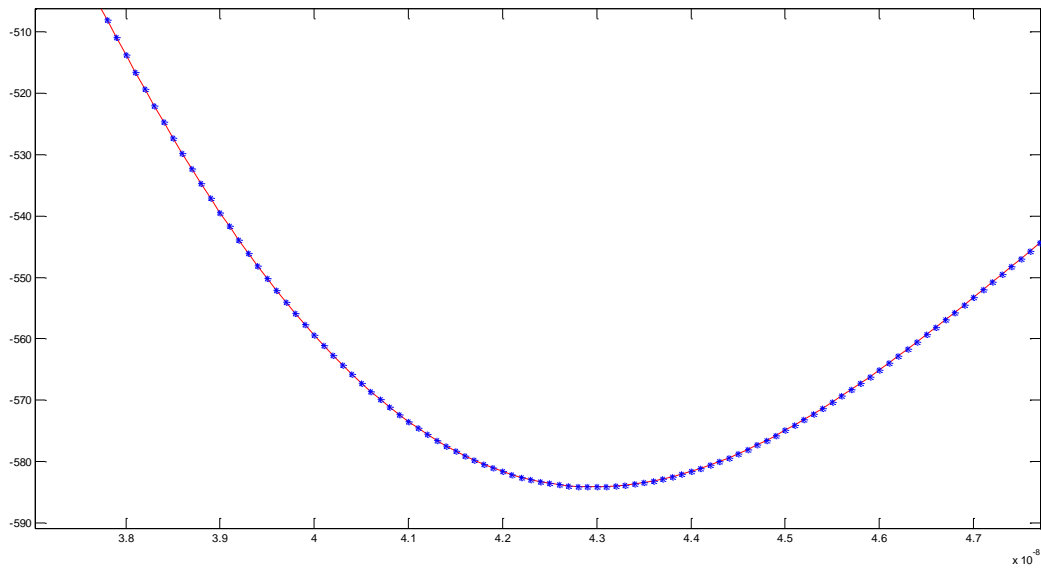


Fig 3.4. Zoom of Fig. 3.3. Matlab code (red) and EMTP simulation (blue)



MULTYCAB

November 2015 Deliverable 4

Document	Deliverable 4
Facilities	-
Revision	Revised
Date	November 2015

Mat model



4 Mat model

The final version of the software will include different basic versions of the mat model.

Single-phase mat model

It will have three possibilities:

- Pure resistive model (R)
- Series R-L model
- Series R-L with a C in parallel

These three mat models are illustrated in next figure.

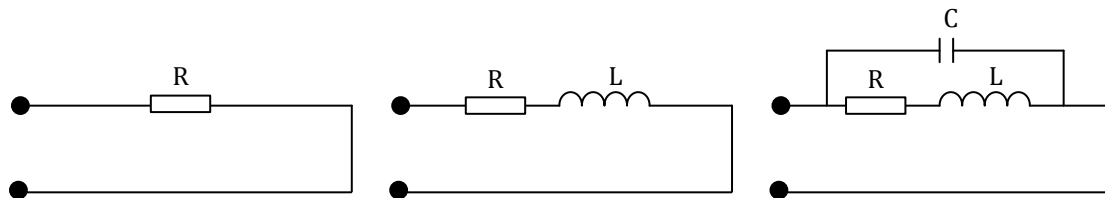


Fig. 4.1. Single-phase mat models

Three-phase mat model

It will have three possibilities:

- Pure resistive model (R)
- Series R-L model
- Series R-L with a C in parallel

An each one of the possibilities above can be connected:

- Not grounded wye connection
- Grounded wye connection
- Delta connection

Therefore, Fig. 4.1 is valid for this case assuming that the drawings correspond to one phase.



MULTYCAB

November 2015 Deliverable 4

Document	Deliverable 4
Facilities	-
Revision	Revised
Date	November 2015

Conclusions



Document	Deliverable 4
Facilities	-
Revision	Revised
Date	November 2015

Conclusions

This deliverable has reviewed different aspects of the MultyCaB project including:

- The voltage output response of the power converter.
- The high-frequency single cell and multi cell cable model.
- The load model
- The comparison of the transient temporal response of a multi cell model with the solver programmed in this project in the Matlab® environment with a commercial solver shows almost identical results, thus validating the code.



Document	Deliverable 4
Facilities	-
Revision	Revised
Date	November 2015

References

Deliverable 2 (D2). Power cable modelling for WIPS electromechanical chain. Project reference: MultyCaB JTI-CS – 632458. Definition of methodology for power cable modelling. February 2015.

Deliverable 3 (D3). Power cable modelling for WIPS electromechanical chain. Project reference: MultyCaB JTI-CS – 632458. Numerical tool first issue. June 2015.

MATLAB. The Language of Technical Computing. <http://es.mathworks.com/help/matlab/>

Y. Weens, Modelisation des cables d'énergie soumis aux contraintes generees par les convertisseurs electroniques de puissance, PhD Thesis report, Université des Sciences et Technologies de Lille, 2006.

M. Moreau, Modélisation haute fréquence des convertisseurs d'énergie. Application à l'étude des émissions conduites vers le réseau, PhD Thesis report, Ecole Centrale De Lille, 2009.