IRPWind

Experimental Validation of High definition Modular Multilevel Converter

Raymundo E. Torres-Olguin†, Michael Smailes, ‡ Chong Ng‡, Pol Paradell□, Jose Luis Domínguez-García□, Giuseppe Guido†, Kjell Ljøkelsøy†, Salvatore D'Arco†
†SINTEF Energy research
‡Offshore Renewable Energy Catapult
□Catalonia institute for energy research IREC

Presenter: Raymundo E. Torres-Olguin

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CATAPULT Offshore Renewable Energy

SINTEF

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- Experimental set-up
- Test procedure
- Some preliminary experimental results
- Conclusions

Background

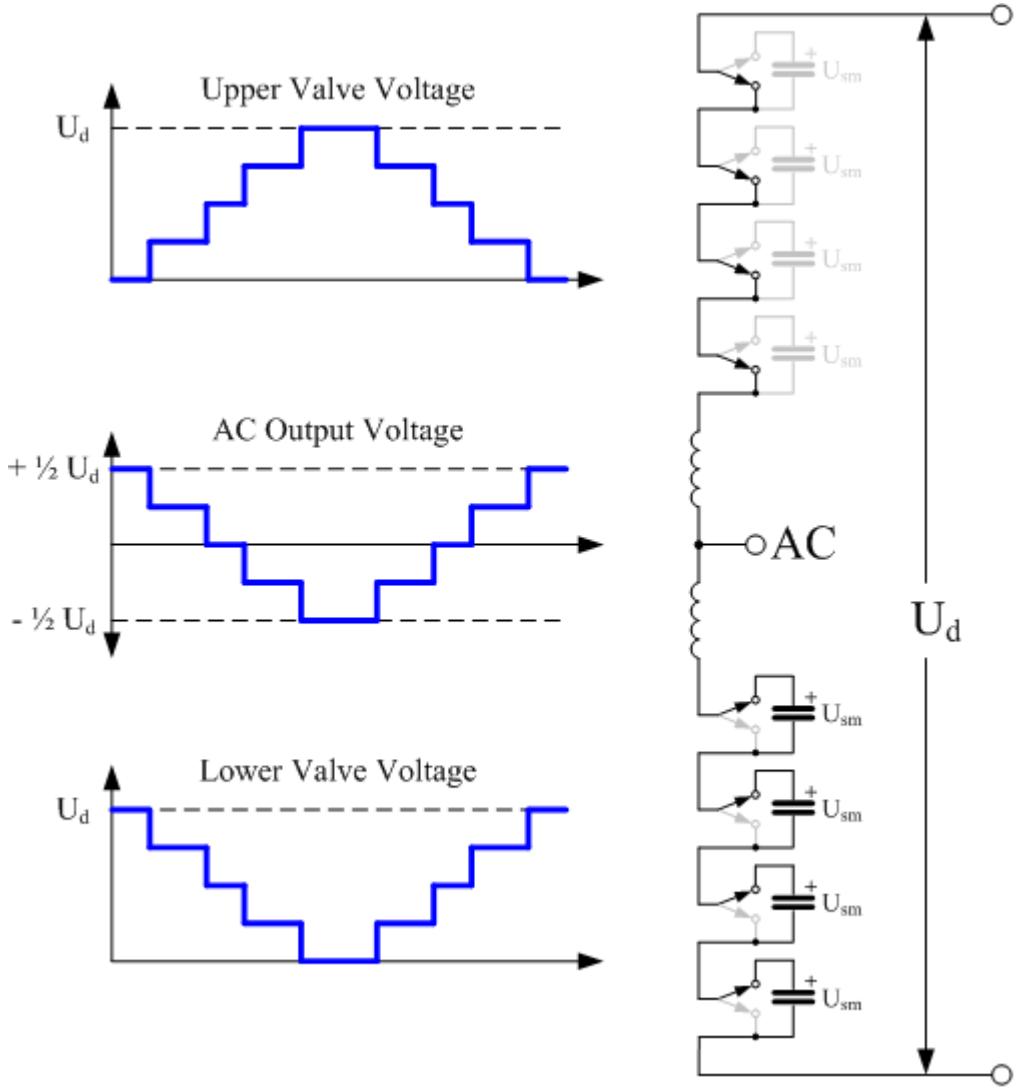
- This work is part of the **1st call for Joint Experiments** organized within the Research Infrastructure WP of IRPWind.
- IRPWind is a European project, which it is aimed to foster better integration of European research activities in the field of wind energy research.
- In Europe, most large research facilities are being devoted to national activities that not necessarily matching the needs of Europe as a whole.
- **1st call for Joint Experiments** has the objective of promoting alignment through joint experiments carried out in European research facilities and its effective use of resources.

Background

- This work focuses on the experimental validation of the concept proposed by ORE catapult High Definition Modular Multilevel Converter (HD-MMC).
- **SINTEF** and **ORE Catapult** are currently working on MMC. The control algorithm for a HD-MMC was developed at ORE Catapult in a simulation enviroment. MMC units have been developed at SINTEF. **IREC** will act as an impartial referee during the comparison of both techniques C-MMC vs HD-MMC since it has no conflict of interest in the proiect.

Introduction

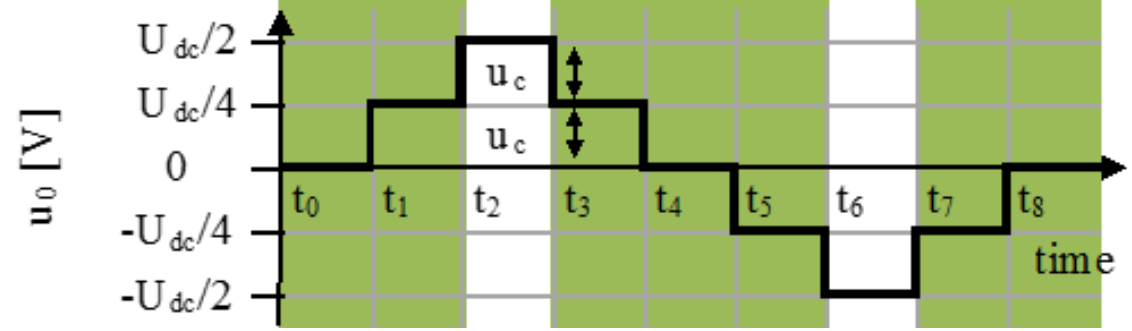
- MMC is emerging topology for offshore wind substations due to its black start capabilities, low Total Harmonic Distortion (THD) and high efficiency.
- The MMC uses a stack of identical modules.
- The multiple voltage steps make the MMC being capable of producing very small harmonic content



Introduction

- In the conventional MMC (C-MMC) each module create one level, so in order to produce a low THD many modules are required.
- What happen if MMC uses an uneven dc values?

Valve	u_c / V	Logic t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8
4p	$U_{dc}/4$	1	1	1	1	1	0	0	1	0
3p	$U_{dc}/4$	1	1	1	0	0	0	0	0	1
2p	$U_{dc}/4$	0	1	1	1	1	1	0	0	0
1p	$U_{dc}/4$	0	0	1	1	0	0	0	0	1
1n	$U_{dc}/4$	1	1	0	0	0	1	1	1	0
2n	$U_{dc}/4$	1	0	0	1	1	1	1	1	1
3n	$U_{dc}/4$	0	0	0	0	0	0	1	1	0
4n	$U_{dc}/4$	0	0	0	0	1	1	1	0	1



Introduction

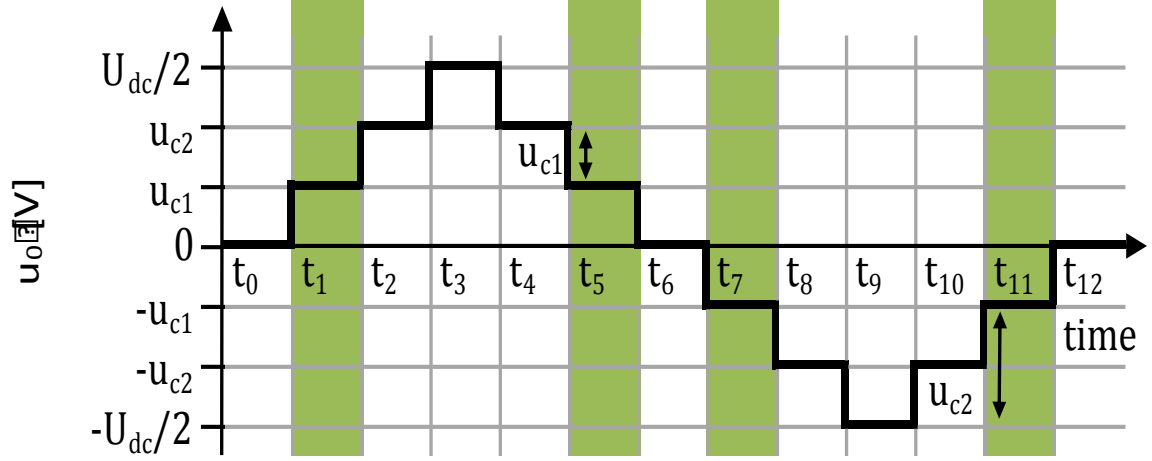
By using uneven dc values in the C-MMC, the novel HD-MMC can produce 7 levels using the same number of modules.

Therefore, THD of the convert is reduced.

Some potential advantages:

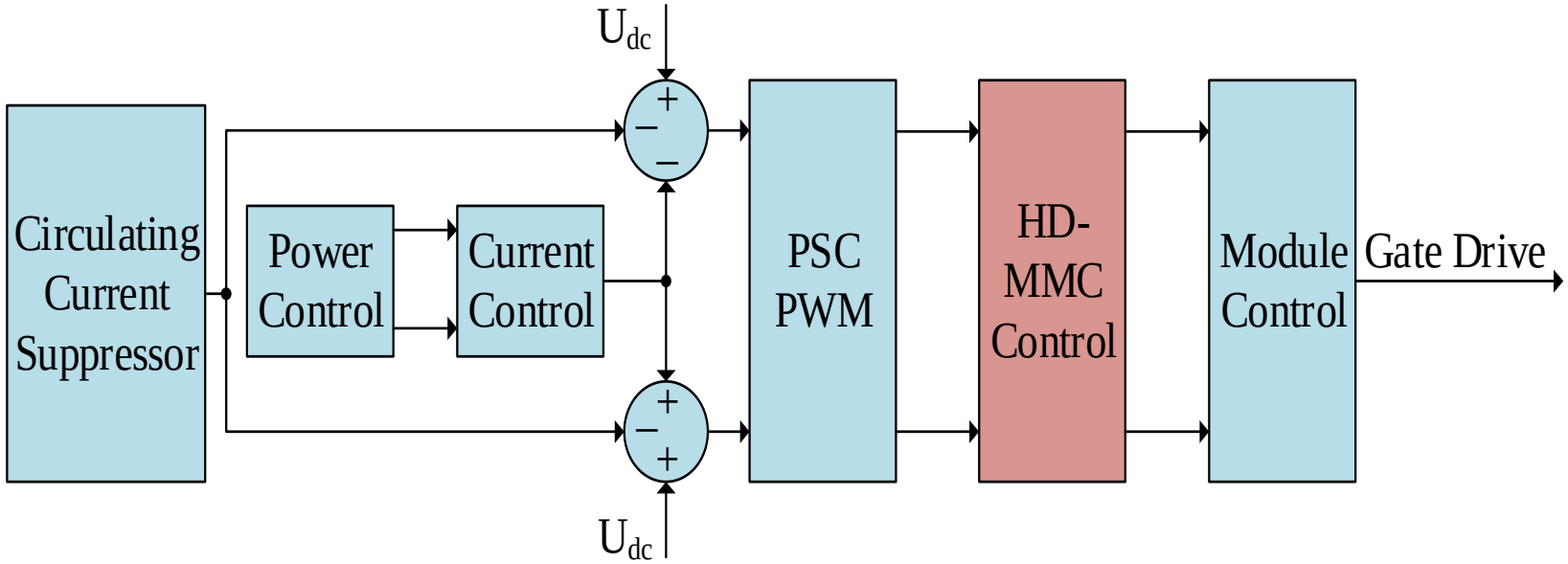
- It can reduce the number of modules required to produce a required THD
- A more compact converter can be achieved reducing platform size and cost
- the utilisation of the MMC's resources could be improved, since redundant states can be repurposed.

SM	u_c	Logic												
	V	t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}	t_{11}	t_{12}
1	u_{c1}	0	1	0	0	1	0	1	1	1	1	0	0	0
2	u_{c1}	1	1	1	0	0	0	0	1	0	1	1	0	1
3	$u_{c2}\,(2u_{c1})$	0	0	0	0	0	1	1	1	1	1	1	1	0
4	$u_{c2}\,(2u_{c1})$	1	0	0	0	0	0	0	0	1	1	1	1	1
5	u_{c1}	1	1	1	1	0	0	0	1	0	0	1	0	1
6	u_{c1}	0	1	0	1	1	0	1	1	1	0	0	0	0
7	$u_{c2}\,(2u_{c1})$	1	1	1	1	1	1	0	0	0	0	0	0	1
8	$u_{c2}\,(2u_{c1})$	0	0	1	1	1	1	1	0	0	0	0	1	0



High definition modular Multilevel Converter

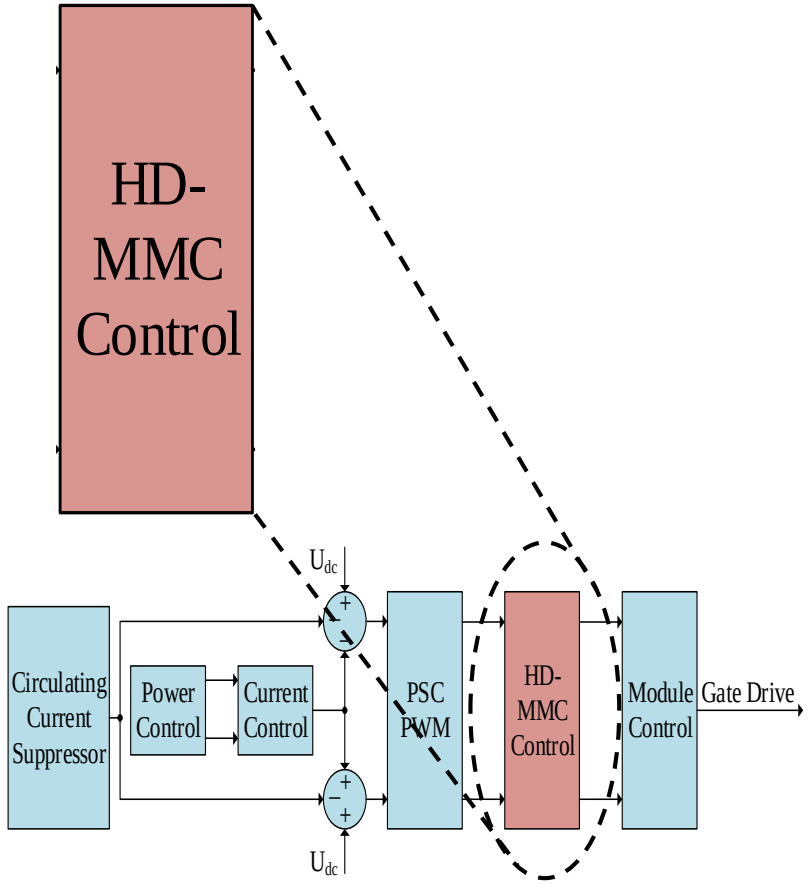
The HD-MMC differs from C-MMC primarily though the addition of a control block between the high level power control and the low level module selection and voltage balancing functions.



High Definition Modular Multilevel Converter

Since each module is no longer equivalent, the set controller must select the correct combination of modules to create the desired voltage level. The controller must also balance the set voltages to ensure that the step size remains constant, minimizing harmonic generation and aiding in converter control.

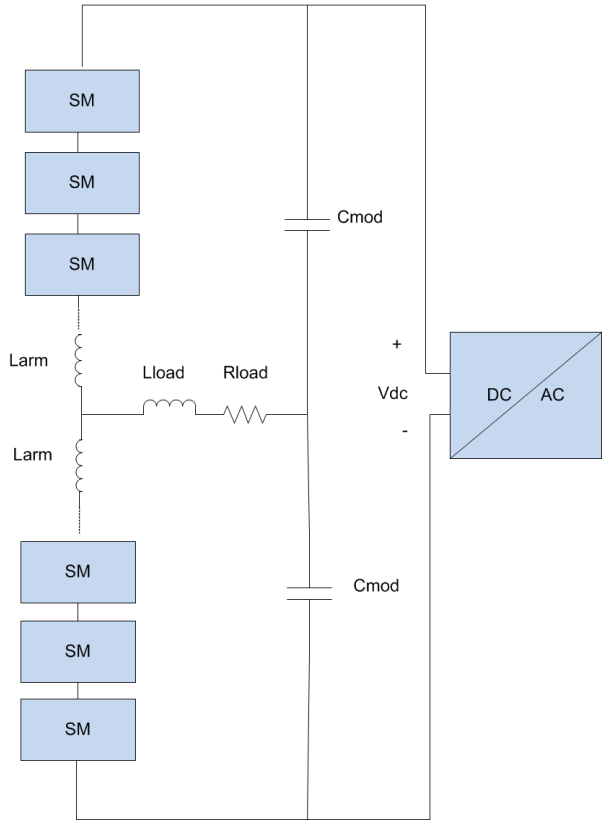
This is done using standard module voltage measurements and arm currents, therefore no additional sensors are required.



Experimental setup

The single phase 18 module MMC was used for the experiment. The proposed test set-up is shown in Figure.

A RL load is used on the AC bus in place of an AC grid as it is thought to be an unnecessary complication for the test.



# of cells per arm	18
DC Voltage	700 V
Rated power	60 kVA
Rated current	30 A
Cell capacitance	21.3mF
Arm inductance	1.4 mH

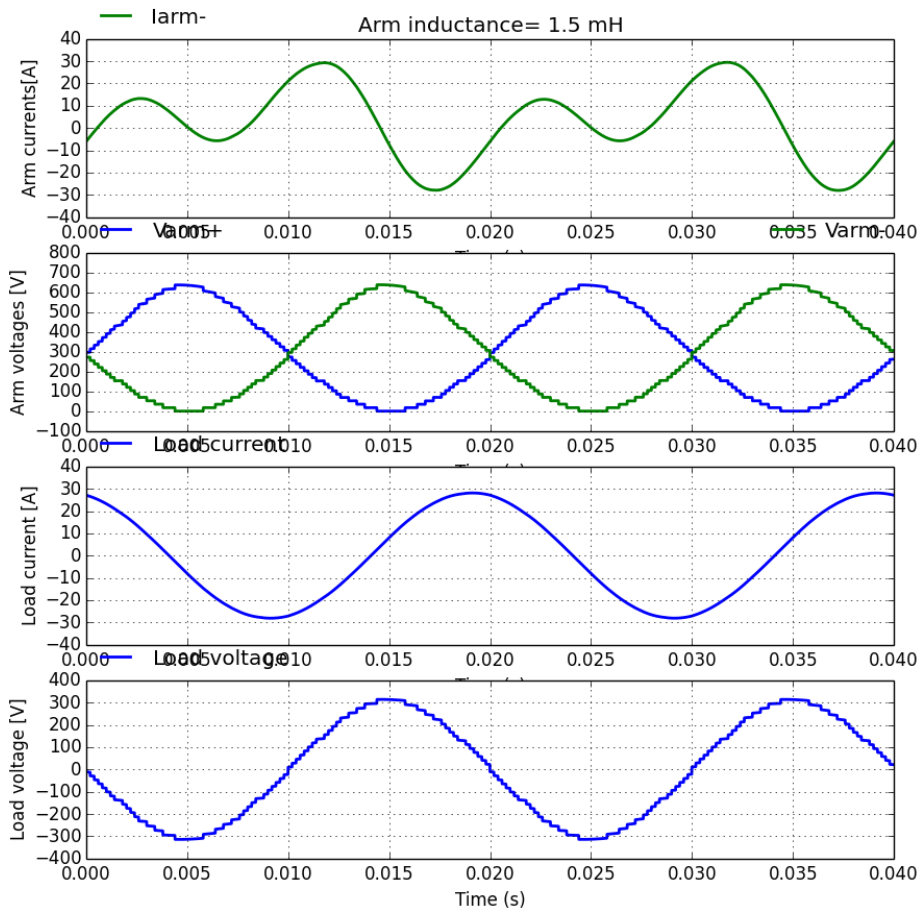
Test procedure

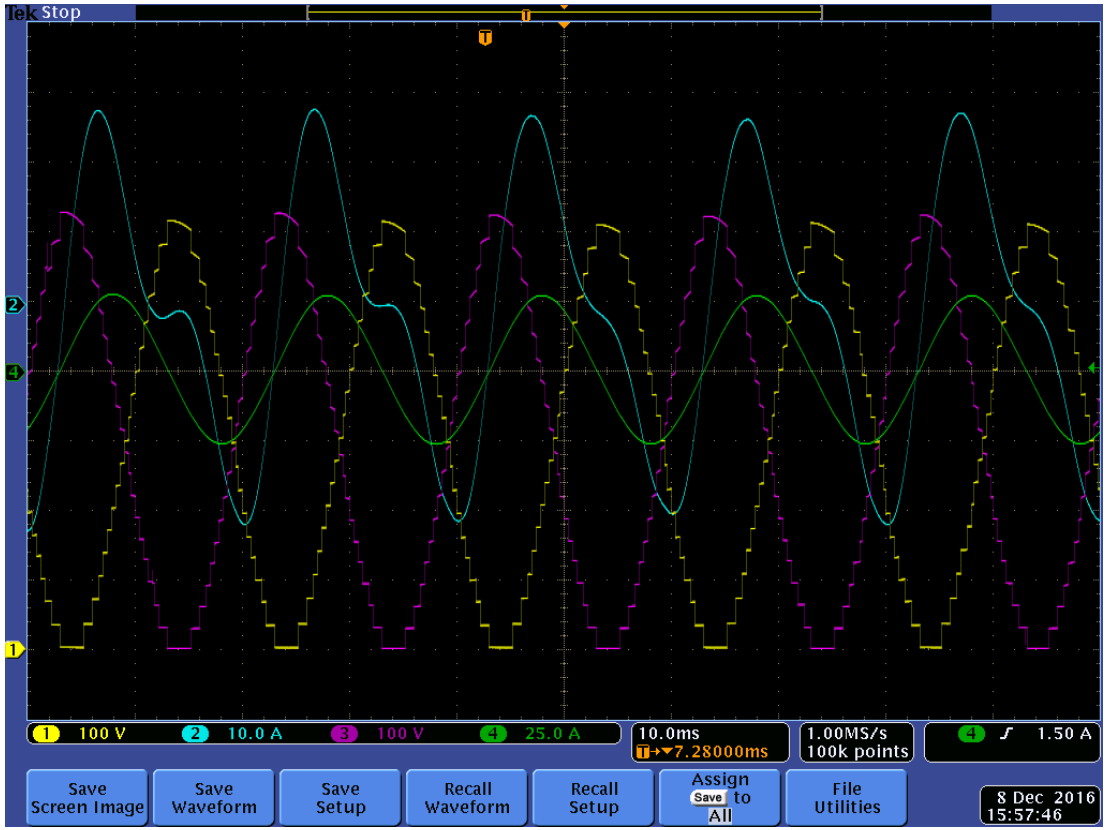
There are 3 main goals of the experiment.

1. Validate the computer models using the test set-up
2. Prove the HD-MMC concept works
3. Compare the performance of the HD-MMC to a C-MMC using THD and efficiency

As THD and efficiency work against each other and the differences between the HD-MMC and C-MMC it would be very difficult to optimise both controls in such a way to ensure a fair test. As a result, several different control combinations for each converter will be tested.

1. Validate the computer models using the test set-up



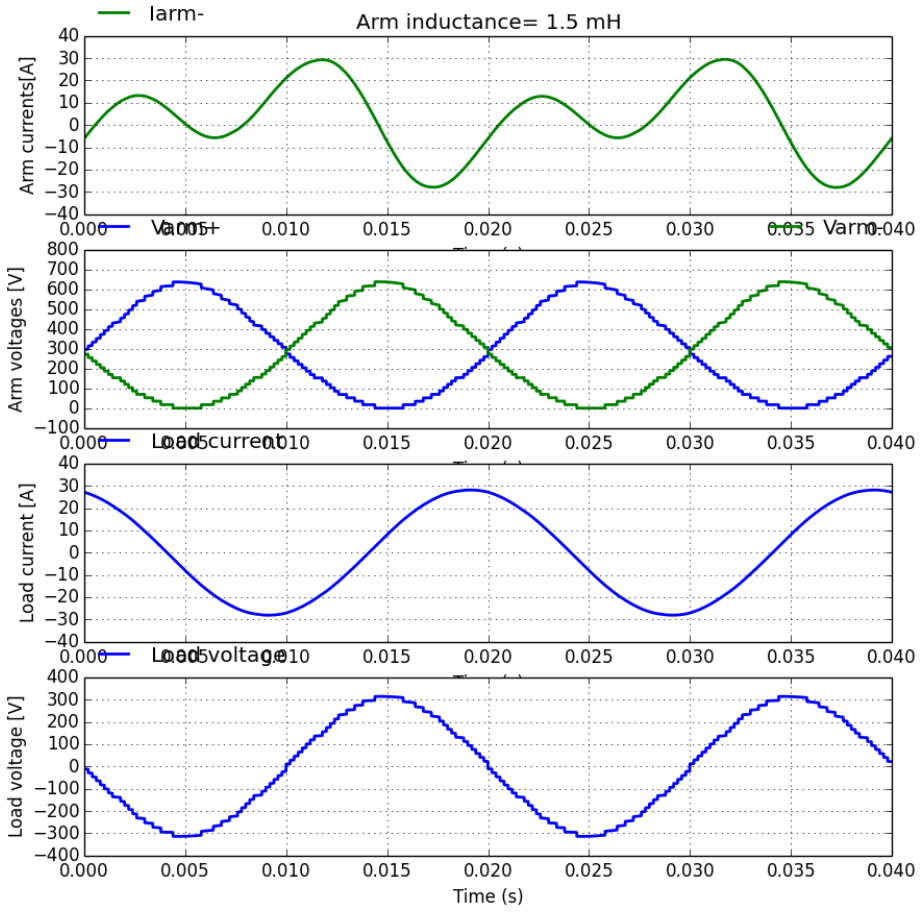


Simulations using NLM

The simulation and experiment match very well

Experiments using NLM

1. Validate the computer models using the test set-up



Simulations using NLM

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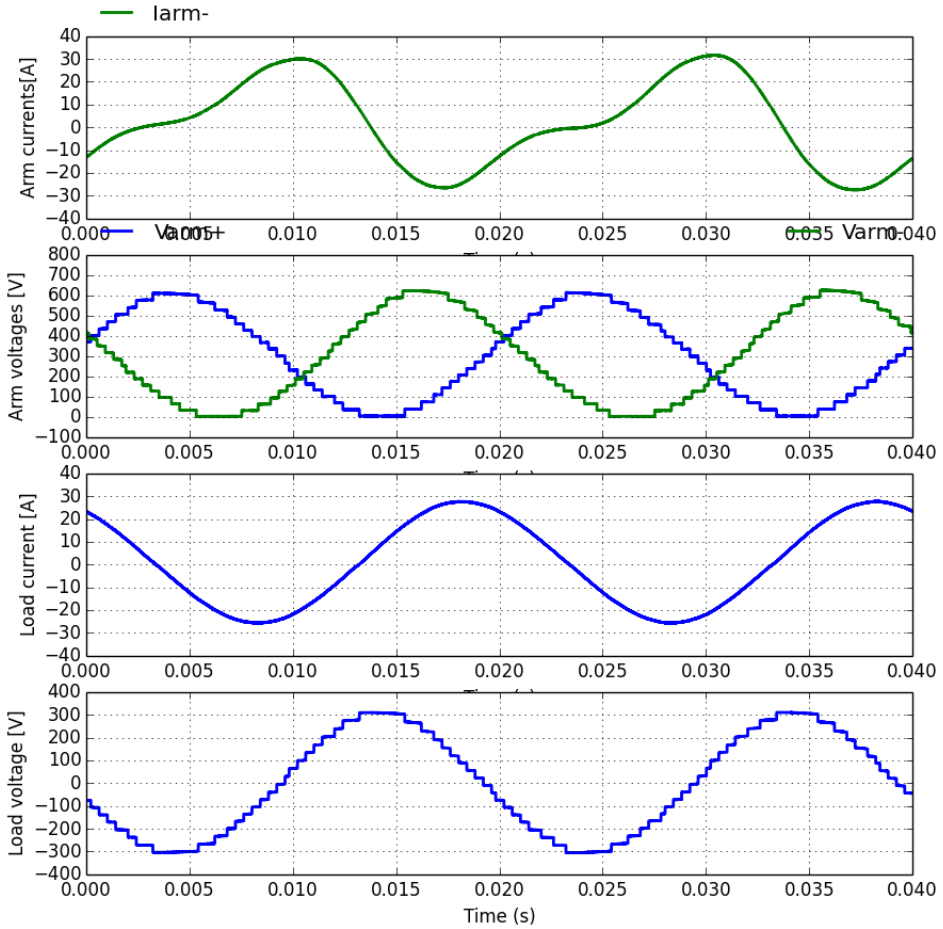
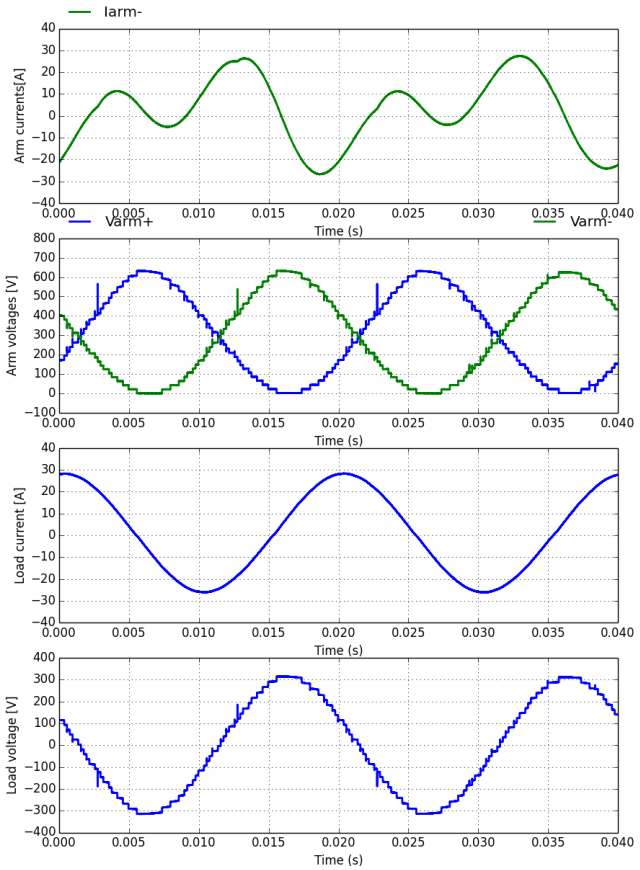


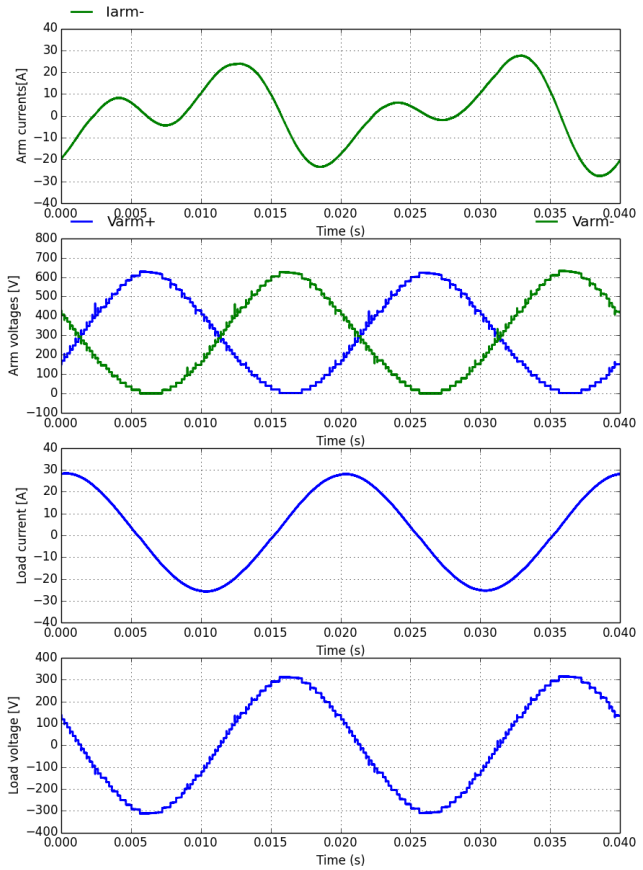
Experiments using NLM

2. Prove the HD-MMC concept works

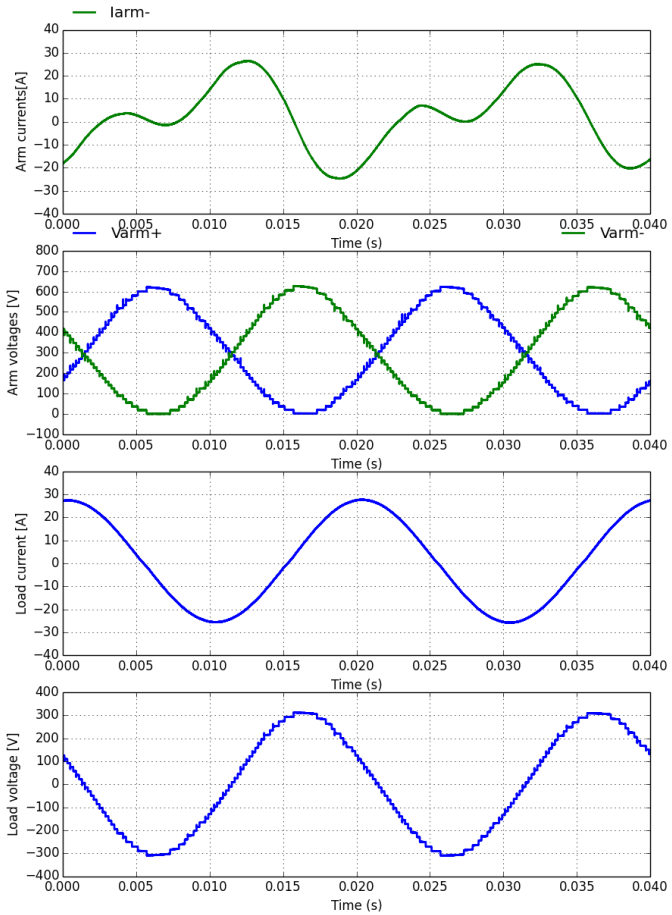
Three cases were proven [fully charged half charged]: [9 9], [5,13] [3,15].



[9 9]



[5 13]

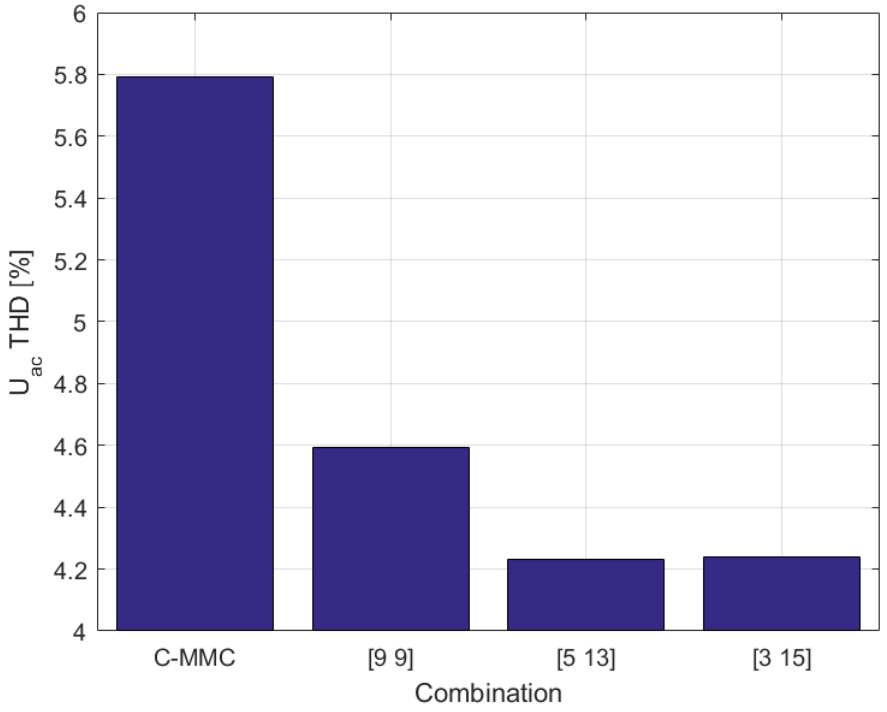


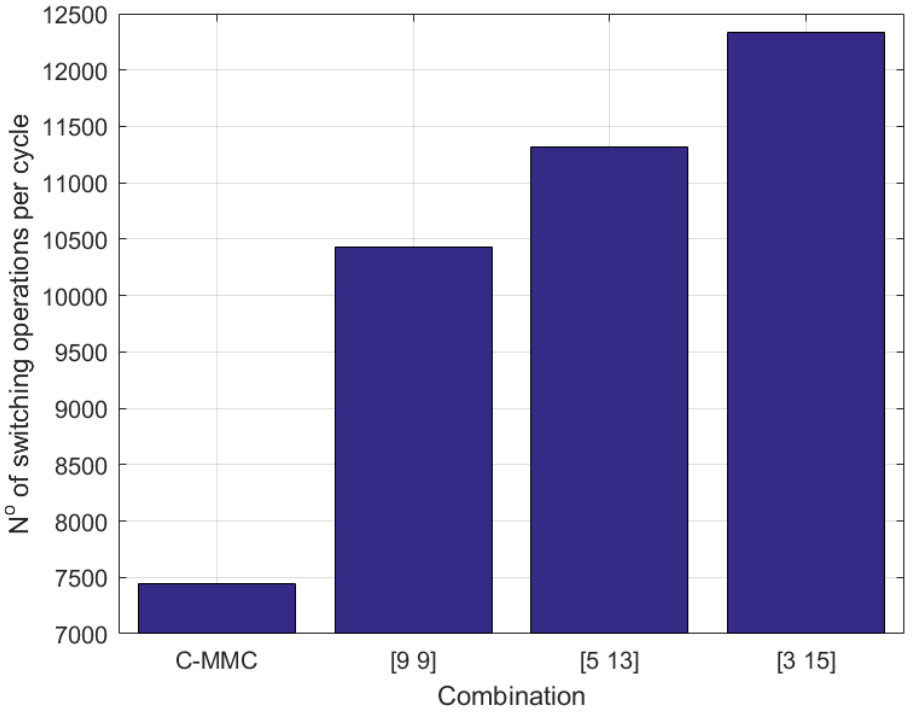
[3 15]

The MMC is able to work with uneven dc voltages as shown in the Figures

3. Compare the performance of the HD-MMC to a C-MMC using THD and efficiency

Three cases were proven [9 9], [5,13] [3,15]. Clearly the THD can be improved using the HD-MMC concept.
In the case of the efficiency, the input and output power of the converter will also be measured to determine the efficiency. However, the difference between the HD-MMC and C-MMC cases will be very small due in part to the type of switches used, MMC is made using MOSFET. Counting the number of switching operations will therefore provide an easier way to infer the efficiency of each converter.





Conclusions

- This work was part of the **1st call for Joint Experiments** organized within The Research Infrastructure WP of IRPWind.
- There were 3 main goals of the experiment.

(i) Validate the computer models using the test set-up. The simulation and experiment match perfectly.

(ii)Prove the HD-MMC concept works. Three cases were proven [9 9], [5,13] [3,15]. The MMC is able to work with uneven dc voltages.

(iii) Compare the performance of the HD-MMC to a C-MMC using THD and efficiency. While the primary goal of HD-MMC is to reduce the THD, however it is important that the losses are not increased significantly as a result.

THANKS