Report

To: MEDOW

From: Abel Ferreira

Subject: Remus Teodorescu Lecture Report

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On the past 18th of June, the visiting professor Remus Teodorescu came from Aalborg University to give the lecture *Modular Multilevel Converters in HVDC Applications- MMC control Desmistification*.

The modular multilevel converter also called Marquart converter (proposed by Rainer Marquart) is presented in Figure 1.

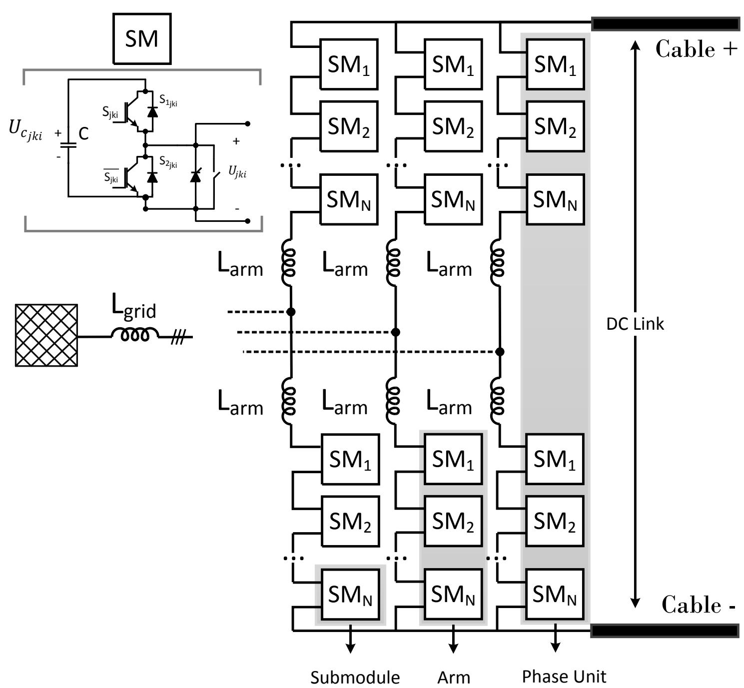

Figure 1: Three phase modular multilevel converter structure.

As the picture show, this converter structure is achieved by the series connection of individual components called *submodules* (SM). By cascading N individual components is obtained what is called the MMC arm. Finally, by assembling two arms in series is obtained the converter phase.

Different submodule topologies can be used in a MMC converter leading to different operating characteristics. However, the professor only focussed in the half-bridge submodule topology. The referred submodule topology can originate only two voltages at its output: either the submodule capacitor is bypassed (short-circuited) if the lower semiconductor is activated or is inserted in the series chain, then, adding a new voltage step in the correspondent arm voltage, that equals to the capacitor voltage.

Additionally, in each arm there is an inductor which is used to limit the current rate rising in case of a dc short-circuit and to limit the circulating currents.

Professor Remus also presented a comparison between the MMC with the previous state of the art solution what is called the two level-VSC (2L-VSC). As strongest points, the MMC has lower switching frequency (typically hundreds of Hz), and, therefore lower switching losses. Due to the large number of levels, the grid filter can be very low that in a 2L-VSC. MMC is also very scalable and modular since those features are based on the number of submodules that are added to the converter. As the weakest points, the MMC has a very complex control structure. The author also affirmed that if the inner converter currents are not actively controlled its amplitude is limited by applying large capacitors on the converter submodules.

The converter operation is based on the connection/ disconnection of the converter submodules. Both upper and lower arms are controlled to generate the phase 'A' ac voltage V_a, by inserting n_U and n_L submodules on the upper and lower arms. The dc current that flow in the DC terminals is equally divided to the three legs to charge the overall capacitors. Since each arm behaves like a single phase source, they undergo second harmonic power variation, and therefore leads to the generation of a second harmonic current flowing between the MMC phases.

The converter control strategies demand a voltage reference to be applied in each converter arm. To overcome this task and additional sorting and selection algorithm is adopted to insert the most suitable submodule capacitors to impose the arm voltage as close as possible to the determined reference (depending on their voltage and number N^*_{on}). This algorithm ranks in an ascending order all the submodules capacitors voltage in each arm. Then, according to the correspondent arm current direction the capacitors are inserted to balance their energy. Precisely, the N^*_{on} capacitors with lower/ higher voltages are inserted if the arm current is positive/negative.

An average MMC model was presented and discussed.

Furthermore, details relating the manufacturing and assembling of several IGBTs generations were presented and discussed. IGBTs module failure discussed were the bond wire lift off, solder join fatigue, bond wire heel cracking, aluminium reconstruction, and corrosion of the bond wires. The IGBTs last generation are called press-pack IGBT. The correspondent failure mode ensures short circuit failure which is usefull for series connected devices as MMC converters.

As conclusions, due to the MMC modularity and scalability, this converter is easily adapted to specific project requirements by adapting the number of submodules. The direct series-connection of IGBTs is avoided (the system then is more robust). The dV/dt is reduced in the MMCs, generating then less electromagnetic noise and also reduces the ac filter required. Lower switching frequency makes this solution more efficient than the previous HVdc generation solutions adopted. Not only on the HVdc field this converter topology is being used, but also for STATCOM and Multi-MW drives applications.