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Losses of Isolated DC-DC

Isolated DC-DC is one of two DC-DC converter topologies that CIGRE WG B4.76 recommends for transmission level applications [1]. As shown in Figure 1, it can be implemented using either transformer of passive LCL filter in the inner AC circuit. LCL filter has no magnetic cores and may have some advantages at higher operating frequencies and DC faults as discussed in [2].
Isolated DC-DC includes 2 MMC bridges which will be similar to the MMC bridges used with HVDC systems. However, the MMC in this application is not connected to the national AC grid and therefore need not comply with Grid code power quality requirements. Also the operating frequency of MMC (and therefore DC-DC converter) can be increased beyond 50 Hz in order to reduce size of converter. This implies that MMC can be optimised for application with DC-DC converters. As an example, some of the MMC parameters that can be modified include: operating frequency, capacitor voltage balancing, number of cells in cascaded valves, size of cell capacitor and arm inductor.

Table 1 shows the parameters of a 320kV/250kV 1GW isolated DC-DC for a range of operating frequencies [3]. It is assumed that all designs have the same key performance requirements like cell voltage ripple and current gradient for DC faults.
It is seen that a DC-DC at 50Hz would have approximately 0.93% total power losses. As frequency increases, total losses increase (primarily because of switching losses), but size and weight reduces. At 500Hz the weight and volume reduces almost 10 times, but losses increase only 2 times. This could be of significance in offshore applications since weight on platforms has high cost penalty. Note that operating frequency can not be infinitely increased because of challenges with heat removal from semiconductors abut also control bandwidth.
With DC-DC intended for onshore applications, it is expected that losses will have higher importance than size and weight, and therefore the operating frequency could be in the range 100-300 Hz. Note that CIGRE B4.76 [1] recommends 150 Hz for high power DC-DC, considering current state of technology and the expected performance requirements. At this frequency, the total DC-DC converter losses are estimated at around 1.1%.

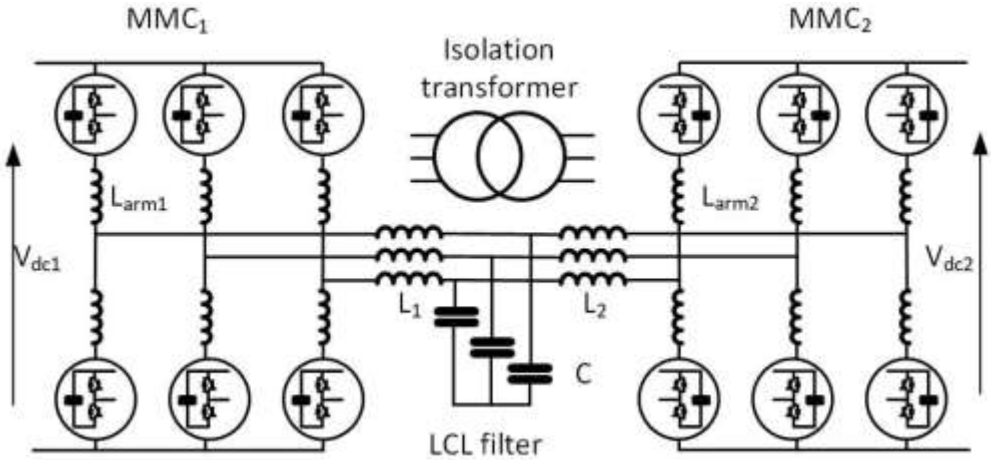

Figure 1. Isolated 3-phase DC-DC converter.

Table 1 Total power losses, weight and volume of 1GW (320 kV-250 kV) LCL DC-DC converter [3].

Freq. (Hz)	LCL weight[1] (Ton)	LCL volume[1] (m^3)	LCL inductors conduction losses (MW)	Total Weight[2] (Ton)	Total volume[2] (m^3)	Total power losses (MW)	Total power losses (%)
50	458	379	1.16	4040	3605	9.32	0.93
100	256	196	0.77	2062	1816	10.35	1.04
200	145	99	0.5	1061	913	12.36	1.24
300	105	69	0.39	721	619	15.17	1.52
400	91	54	0.34	561	470	18.08	1.81
500	71	43	0.29	447	373	20.97	2.1
600	62	37	0.26	368	350	23.72	2.37
700	55	32	0.24	325	268	26.94	2.69
800	49	28	0.22	289	236	29.72	2.97
1000	42	23	0.19	230	187	36.17	3.62

References :

[1] CIGRE WG B4.76, DC-DC converters in HVDC grids and for connections to HVDC systems, *CIGRE TB 827, Paris, March 2021*

[2] D Jovcic "High Voltage Direct Current Transmission: Converters Systems and DC Grids", 2nd edition Wiley, 2019, ISBN: 978-1-119-56654-0, 1st edition Wiley, 2015, ISBN: 978-1-118-84666-7,

[3] A. Jamshidifar, M. Hajian, **D.Jovcic** and Y Audachya, "High power MMC VSC Optimal Design for DC/DC converter applications" IET Power Electronics Vol. 9, issue 2, February 2016, pp 247-255