Power electronics for energy storage

Note Title 11/20/2011

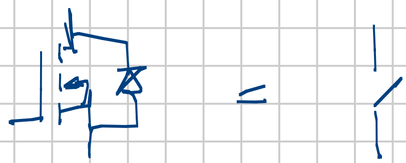
- Batteries and ultracaps:

↳ 2 Functions for the power electronic interface

↳ Control charge/discharge

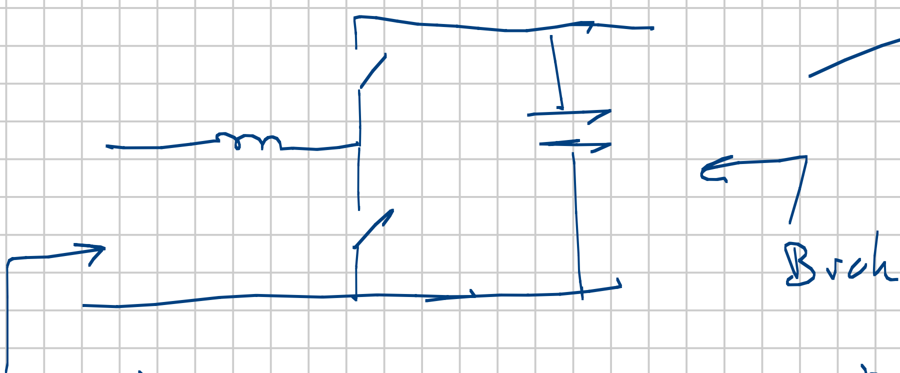
↳ Cell equalization

Consider →



Non-isolated converters for charge/discharge control

1/2 Bridge (aka boost/buck



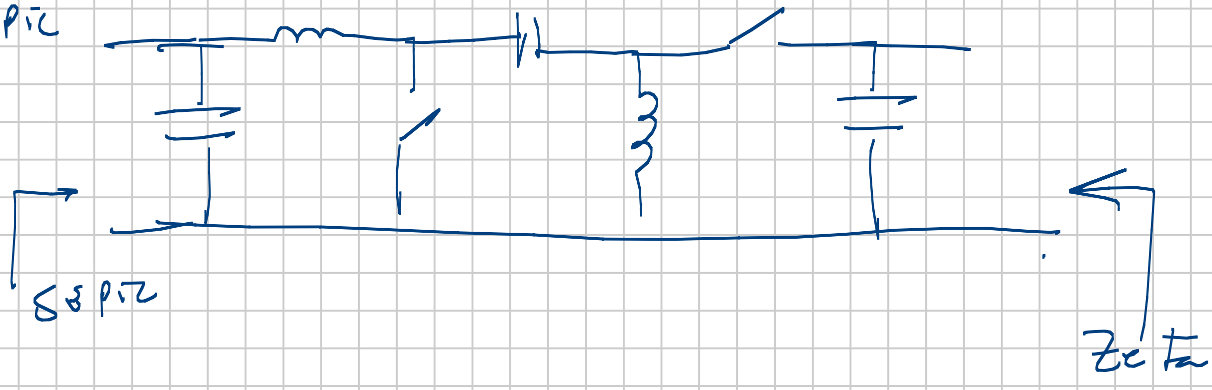
→ No diodes → All active switches (but depending the operational mode may only act as diodes)

← energy storage on this side because of its low voltage

Also some battery technologies need to have their current controlled when they are being charged → e.g. Li-ion

Ćuk

SEPIC



Advantages of non-isolated topologies

- simple
- high efficiency
- low cost
- high reliability

Disadvantage → Max. voltage step-up ratio ≃ 4x

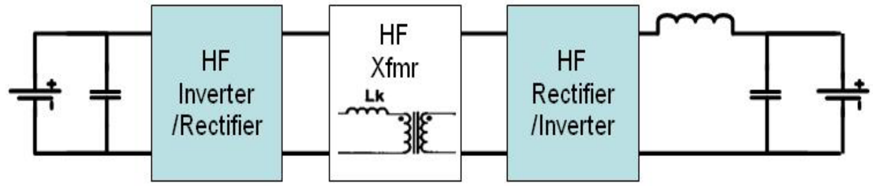
1/2 Bridge tends to be more efficient and cost less than the other configurations.

Isolated converters

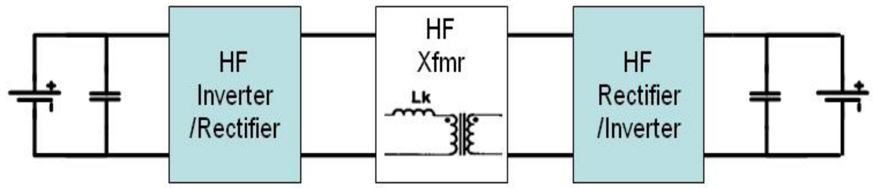
↳ There is a good summary here

Review of High Power Isolated Bi-directional DC-DC Converters for PHEV/EV DC Charging Infrastructure

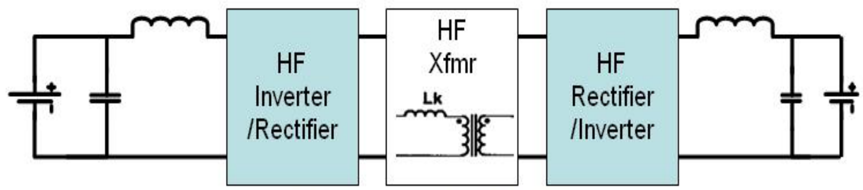
Yu Du Srdjan Lukic Boris Jacobson, Alex Huang



One voltage-fed and one current-fed DC side

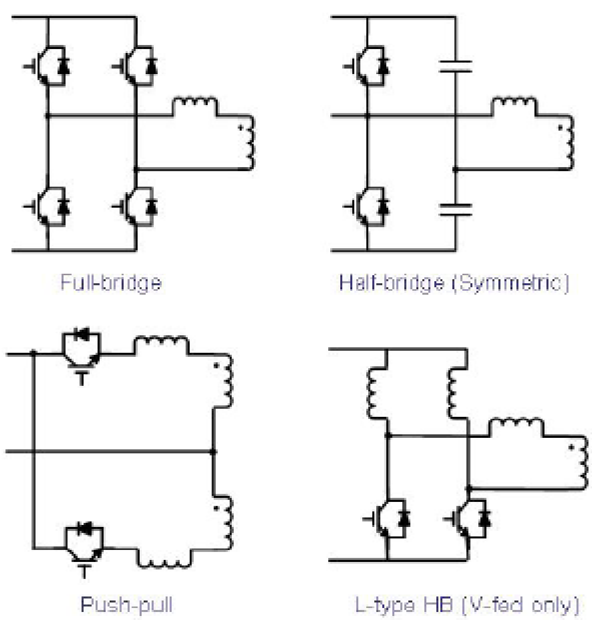


Two voltage-fed DC sides

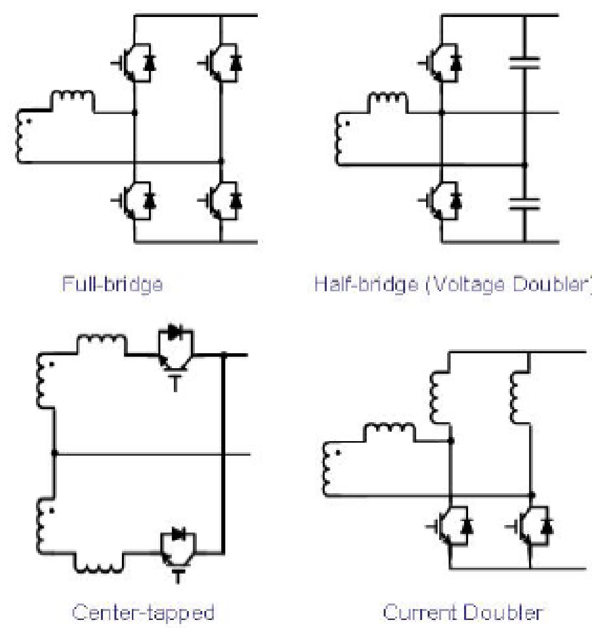


Two current-fed DC sides

Inverter → Rectifier →



(a) Major topologies for high frequency inverter



(b) The counterpart topologies for high frequency rectifier

Notice the correspondence

Voltage stress in full bridge = voltage stress in half bridge

current " " " " = $\frac{1}{2}$ current " " " "

- Rest of topologies suitable for low voltage and high current application because of stress switches

voltage fed → current-fed

Low voltage — High voltage

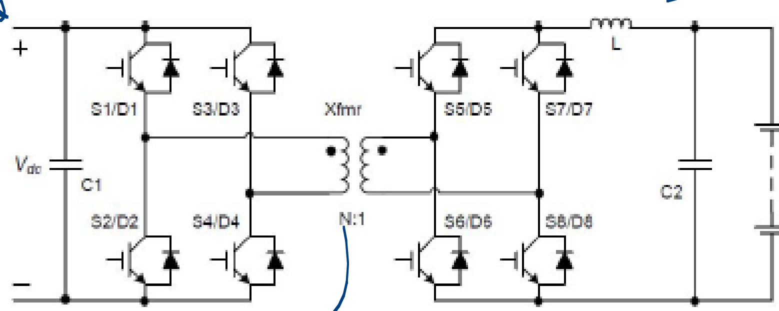


Fig. 4: Bi-directional DC-DC converter based on a voltage-fed full bridge and a current-fed full bridge

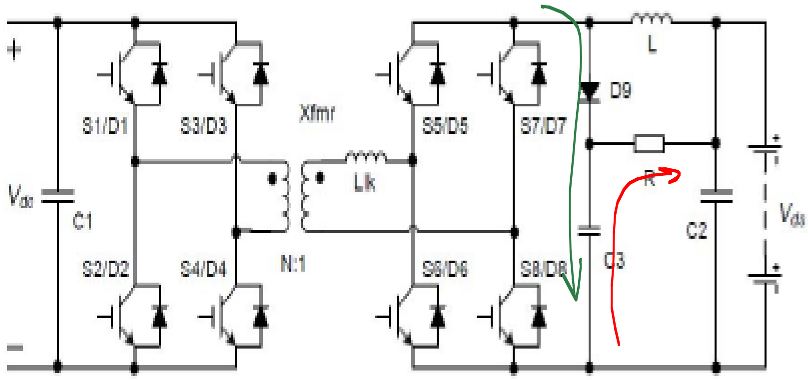
Issue in high power applications → leakage inductance

→ High voltage spikes on switches when switching

→ Lower efficiency

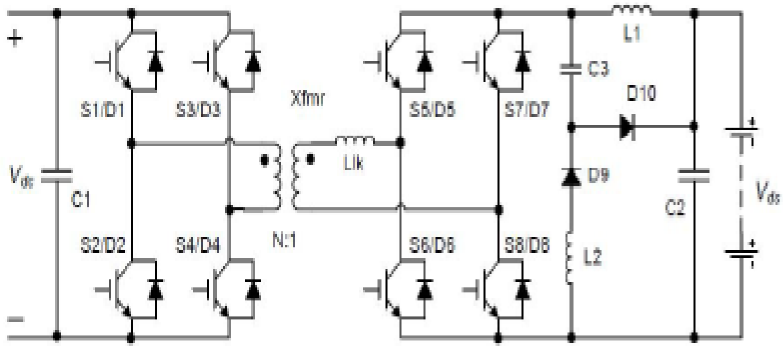
→ Possible reliability issues

Energy of spikes transferred to capacitor which limits the spike



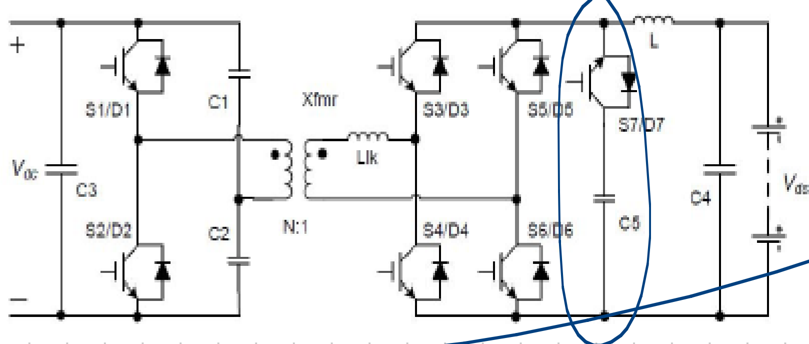
lossy RCD snubber

Extra energy dissipated to resistor



lossless but more components

Active-clamp

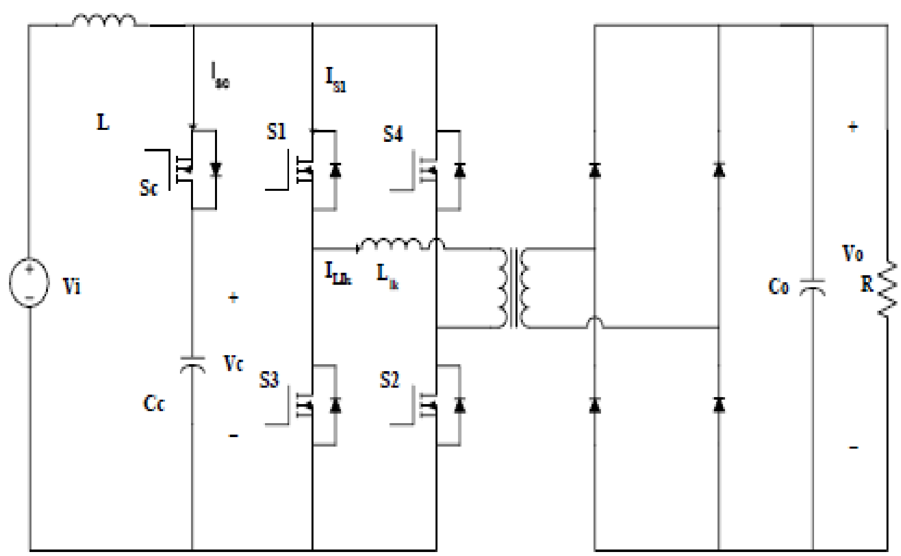


Let's see it in more detail from

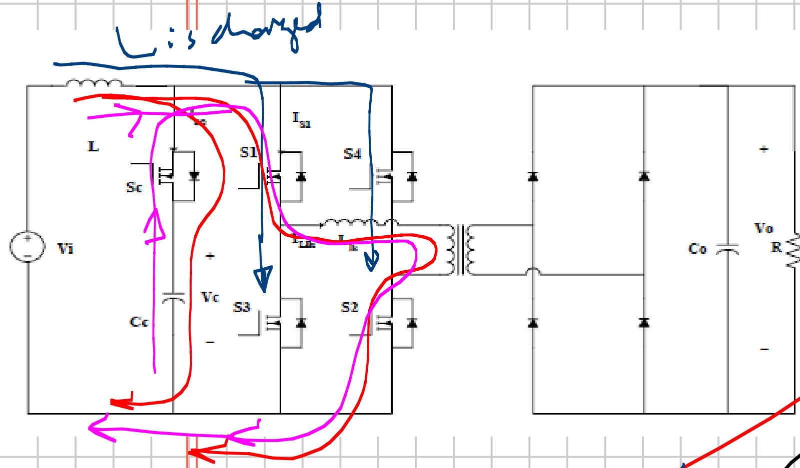
A Soft-switching Active-Clamp Scheme for Isolated Full-Bridge Boost Converter

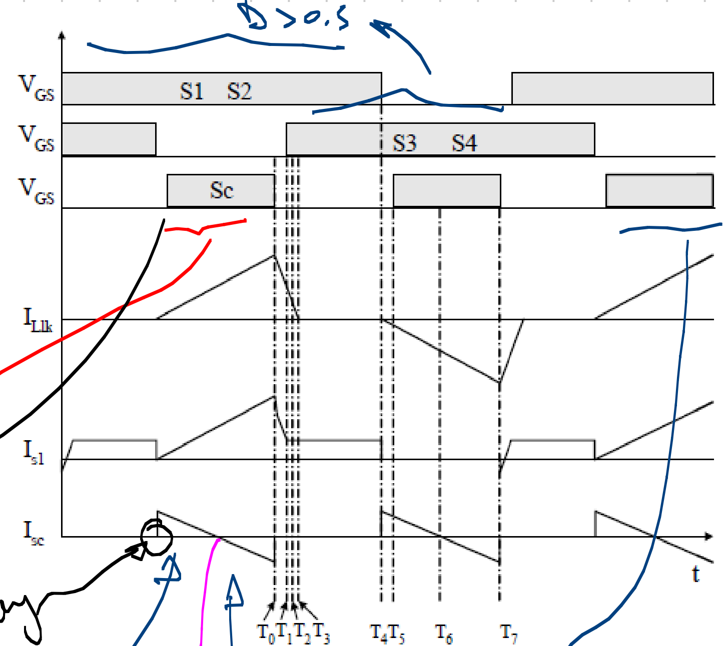
En-Sung Park

Sung Jin Choi, J. Moon Lee and B.H. Cho



L is charged





- L is discharged
- L is discharged

Zero current switching

current goes through diode

Cc is charged

Cc is discharged

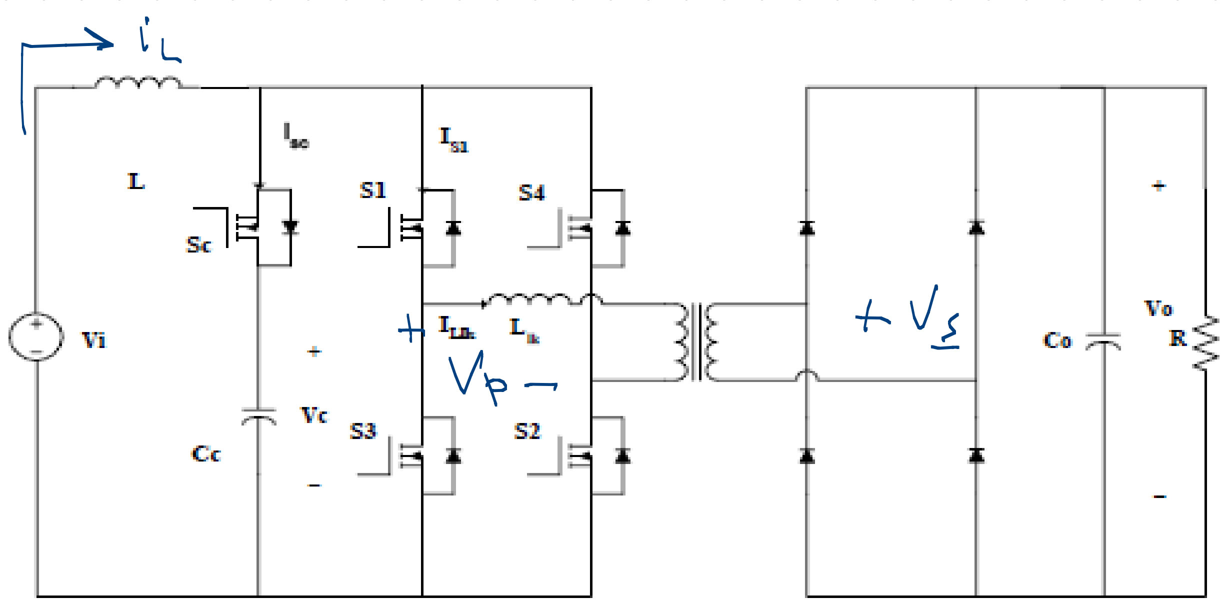
L is discharged

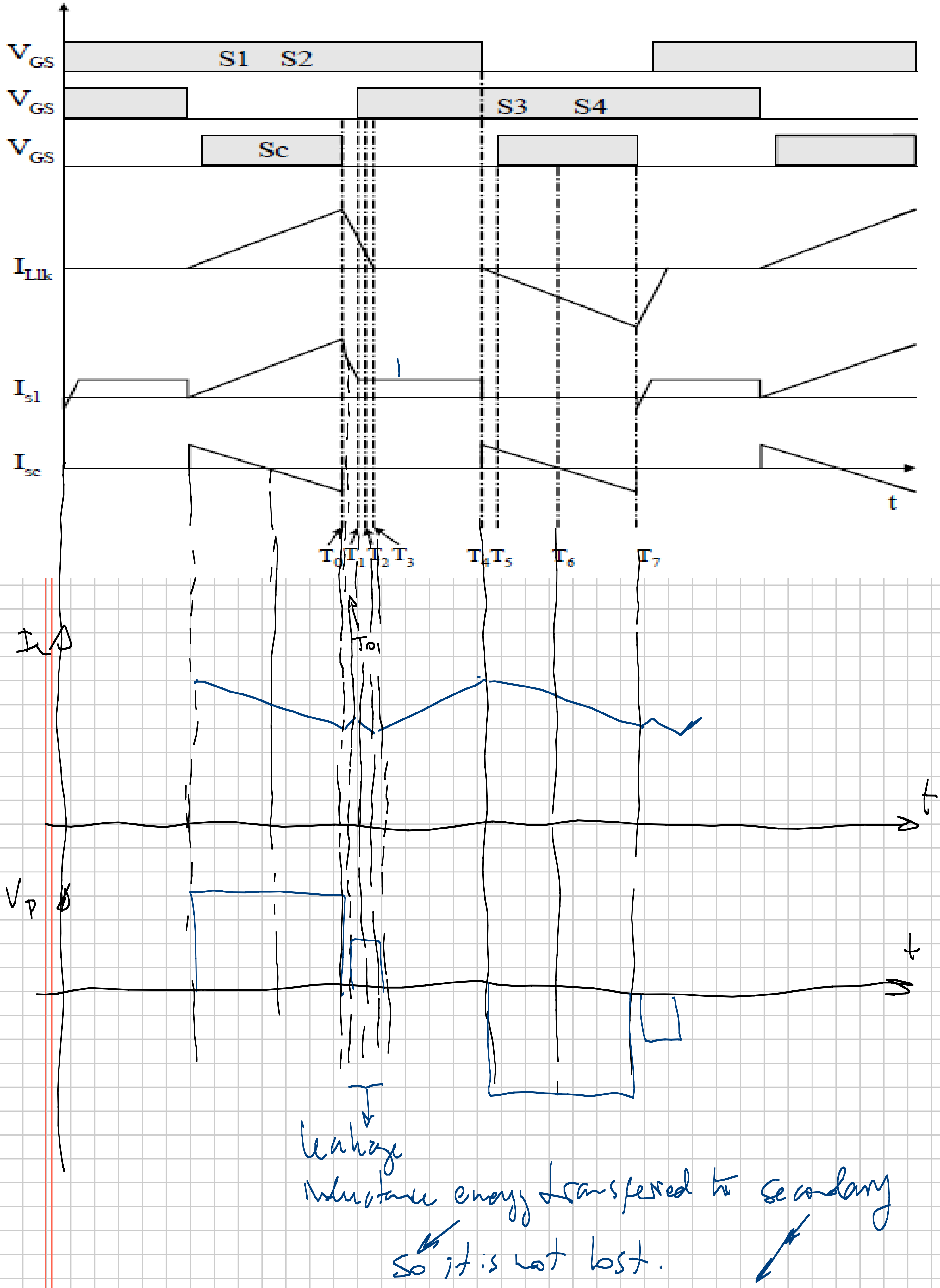
Switched is switched on → ZVS

L is charged in T1 to T4

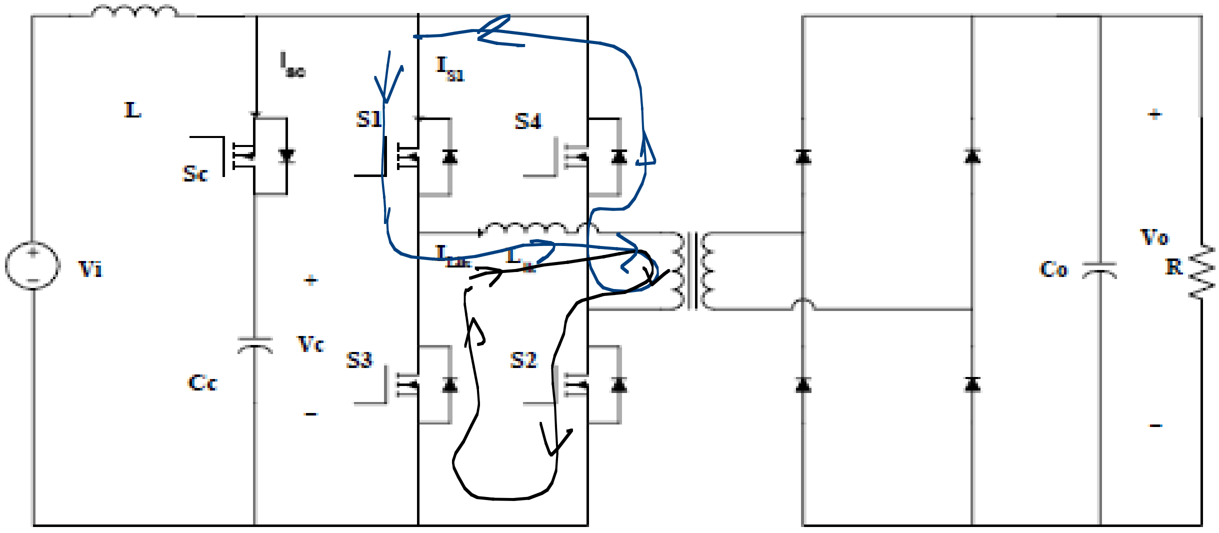
- When either (S1, S2) or (S3, S4) are switched off then the diode in Sc starts to conduct and clamps the switches voltage to Vin.

Some more details

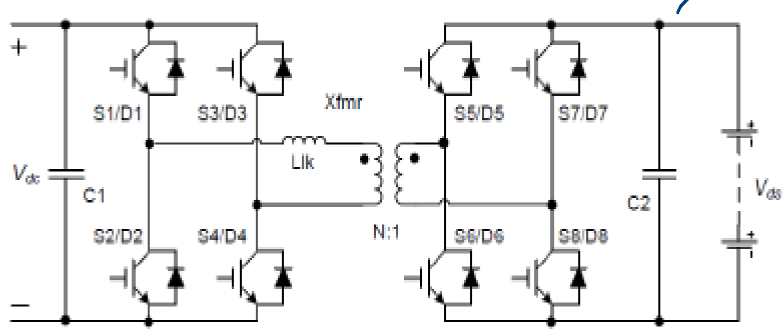




V_{GS}
S1 S2
V_{GS}
S3 S4
V_{GS}
Sc
I_{Llk}
I_{s1}
I_{sc}
t
T_0 T_1 T_2 T_3 T_4 T_5 T_6 T_7
T_{01}
I_L
t
V_p
t
leakage
inductance energy transfered to secondary
So it is not lost.



Now, let's continue with the energy storage converters:



New voltage interface

Fig. 10: Bi-directional DC-DC converter based on two voltage-fed full bridges

1/2 Bridge

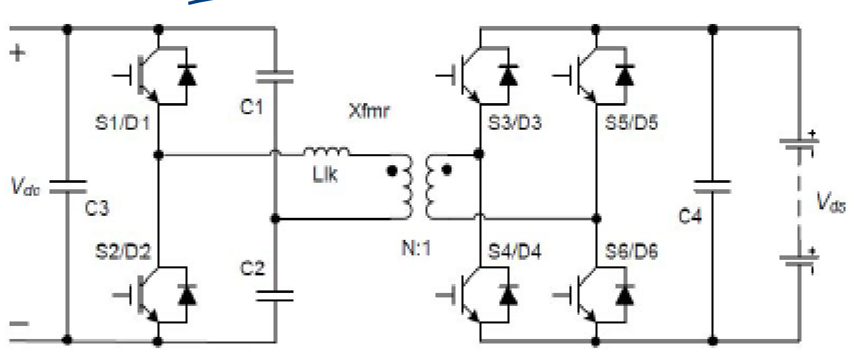


Fig. 11: Bi-directional DC-DC converter based on a voltage-fed half bridge and a voltage-fed full bridge

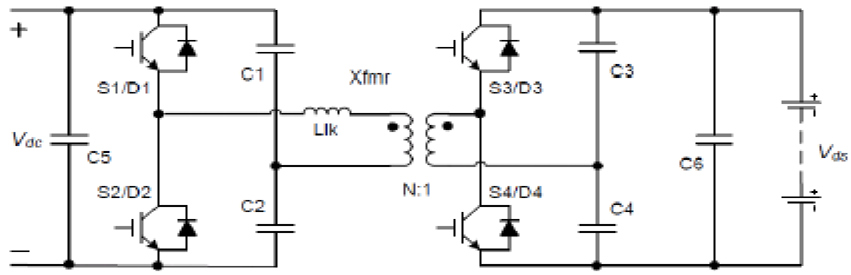


Fig. 12: Bi-directional DC-DC converter based on two voltage-fed half bridges

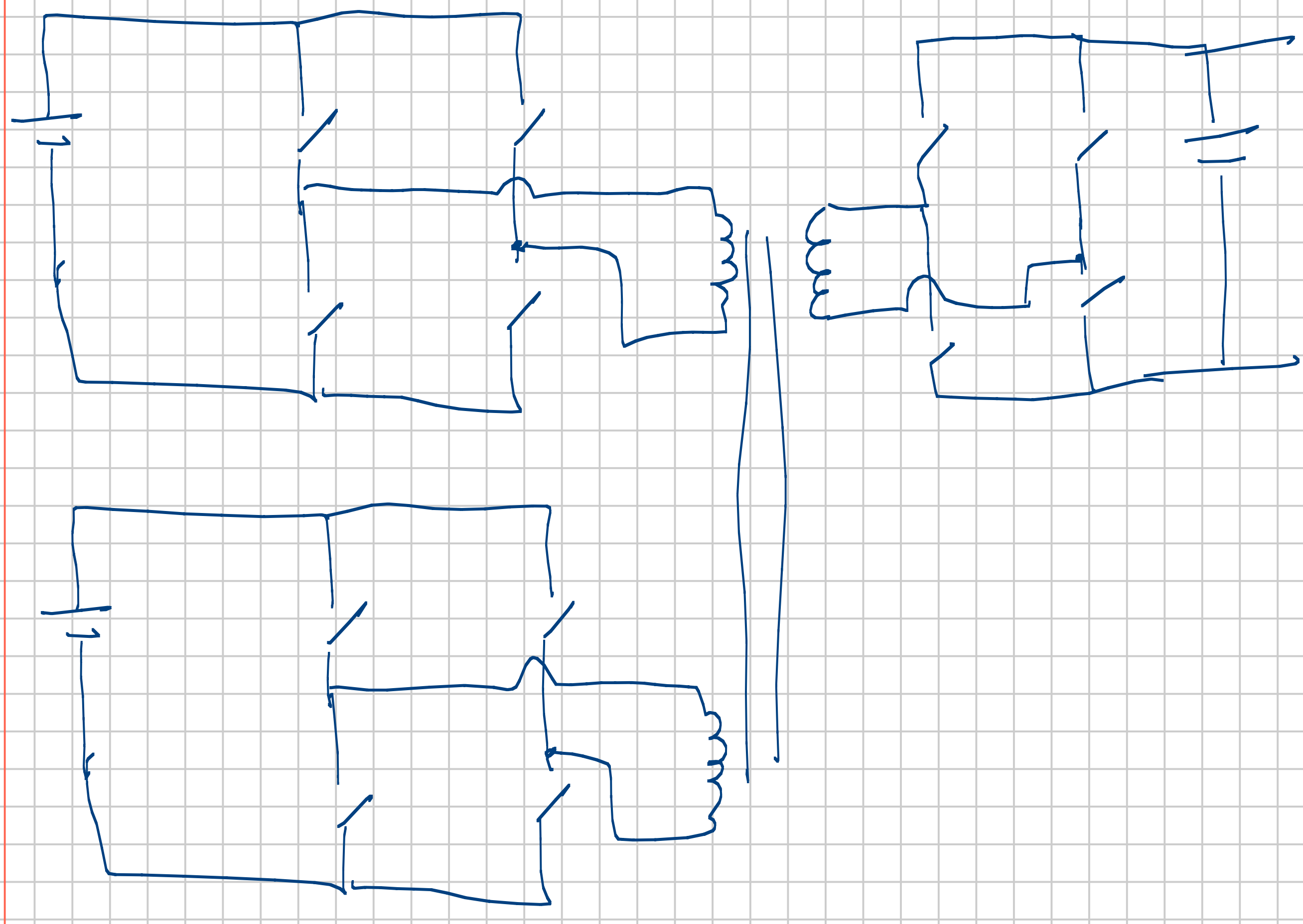
Advantage → potential higher efficiency compared to current source due to < stress.

But

Disadvantages → Not easy to have high efficiency with light loads

Narrow voltage range for optimal operation → Problem when the input voltage is expected to drop due to battery discharge

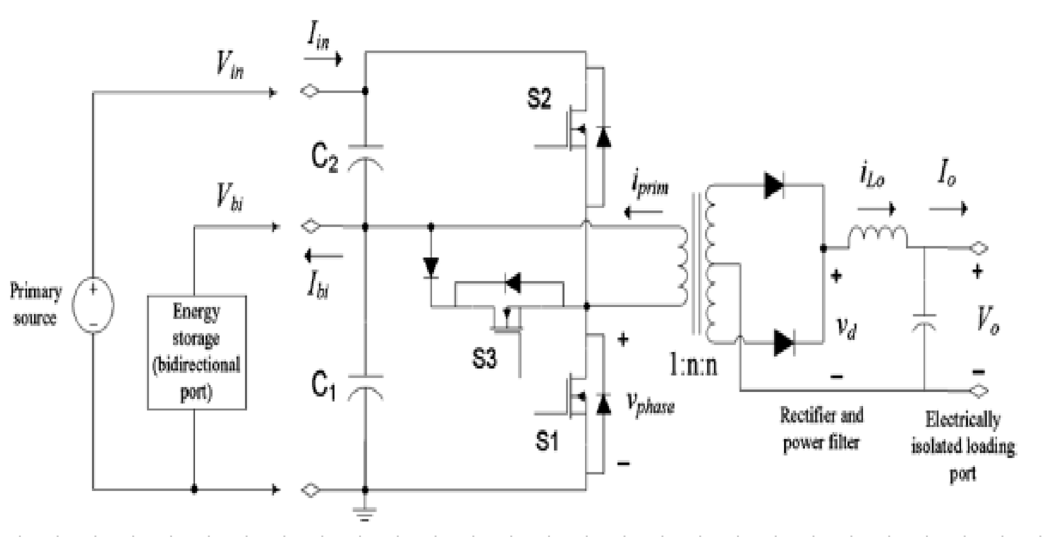
The full bridge can be extended as multiple input configuration

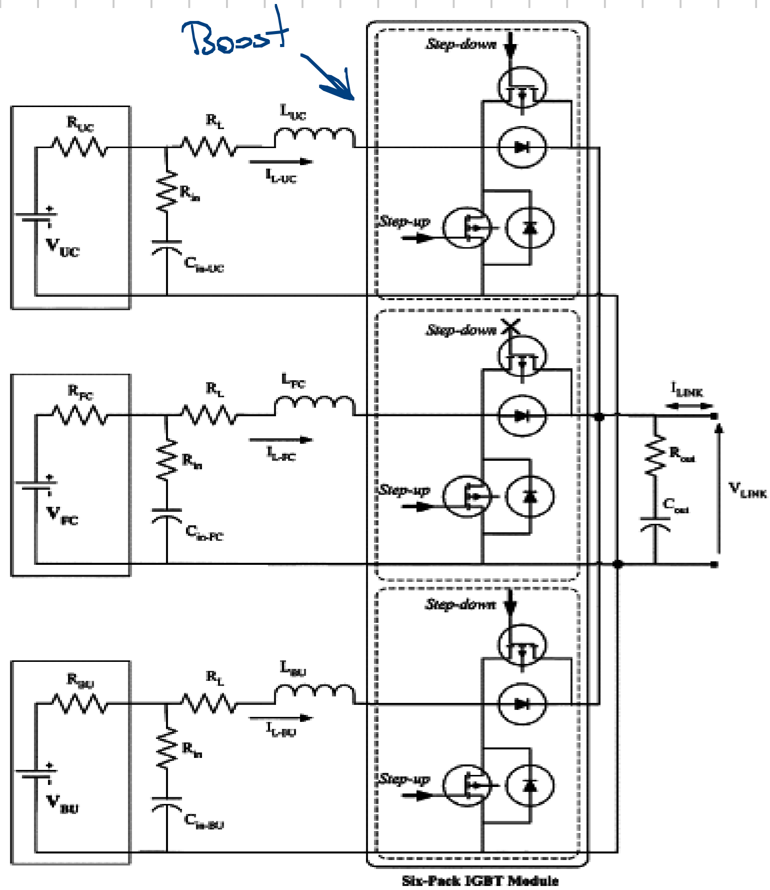


Other bidirectional MICs.

Tri-Modal Half-Bridge Converter Topology for Three-Port Interface

Hussam Al-Atrash, *Student Member, IEEE*, Feng Tian, *Student Member, IEEE*, and Issa Batarseh, *Fellow, IEEE*





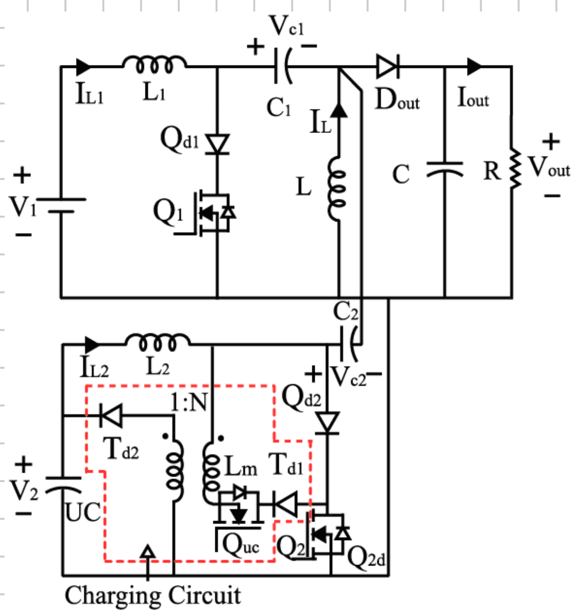
IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 20, NO. 5, SEPTEMBER 2005

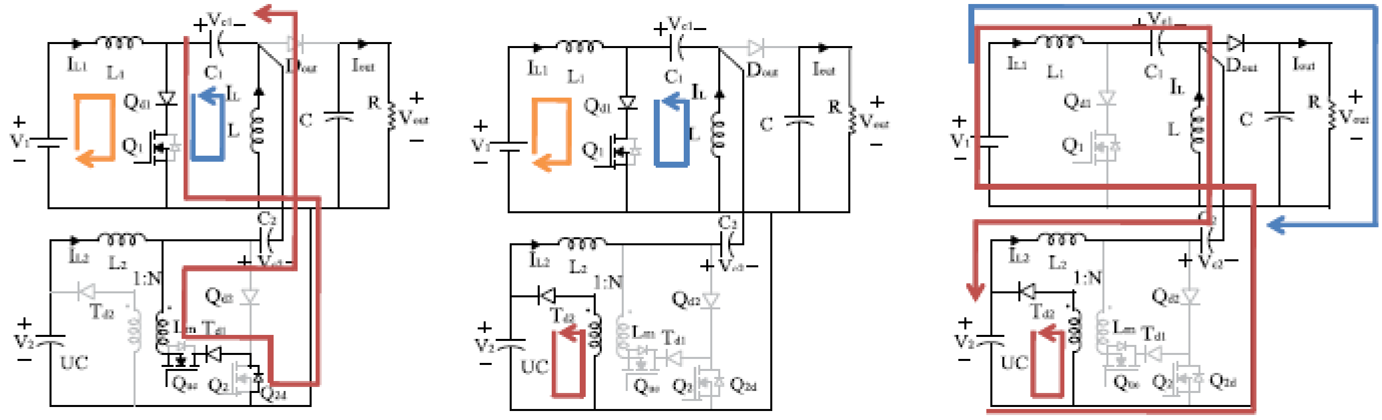
Design of Multiple-Input Power Converter for Hybrid Vehicles

Luca Solero, *Member, IEEE*, Alessandro Lidozzi, *Student Member, IEEE*, and Josè Antenor Pomilio, *Senior Member, IEEE*

A Multiple-Input SEPIC with a Bi-Directional Input for Modular Distributed Generation and Energy Storage Integration

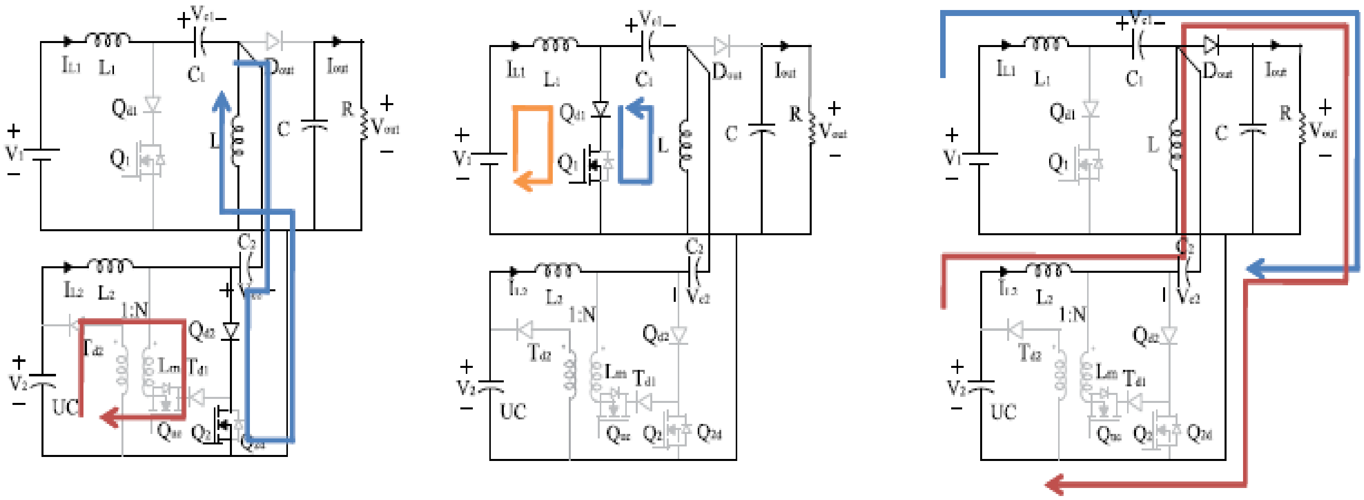
Juyoung Jung   Alexis Kwasinski





Mode 1 ($q_1(t)$=1, $q_{uc}(t)$=1) **Mode 2** ($q_1(t)$=1, $q_{uc}(t)$=0) **Mode 3** ($q_1(t)$=0, $q_{uc}(t)$=0)

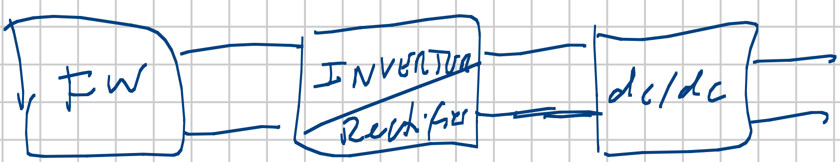
charge mode



Mode 1 ($q_1(t)$=1, $q_2(t)$=1) **Mode 2** ($q_1(t)$=1, $q_2(t)$=0) **Mode 3** ($q_1(t)$=0, $q_2(t)$=0)

Discharge mode

For flywheel I need controlled ac as output on one side.



Let's go back to batteries.

another important need is cell balancing.

what's the problem with cell balancing?

All cells need to be kept "floating" at a given voltage.

When they discharge their voltage should not fall below a given value

With many cells connected in series cells will have a slight voltage difference → eventually due to this voltage difference some cells may have a voltage too low and fail.

So the goal of cell balancing circuits is to keep all cells at the same voltage.

Reference →

Battery Balancing Methods: A Comprehensive Review

Jian Cao*, Nigel Schofield** and Ali Emadi***

Shunt active balancing → Removes extra energy from overcharged cells and transfers that energy to undercharged cells.

(see paper).