Software-Defined Power Conversion

1. Backdrop

In power electronics, cost is saved and reliability is enhanced if common hardware can be re-used widely across a range of applications. This becomes particularly practical and advantageous in the case of multilevel power conversion stages. The advantages of such approaches, and practical means of implementing these in a cost-effective fashion at 300W-3kW power levels, have been highlighted in companion documentation from ICERGi. Usage of digital control allows the functionality to be determined using software control, with a unique "personality" assigned in this manner to each hardware module implementation.

2. The Multilevel Stacked Multi-Phase Leg

The advantages of the multilevel power converters as illustrated in Figure 1 have been well documented for mid-range power factor correction (PFC) [1]. Specifically, efficiency is improved as all switching is undertaken using fast-switching low-voltage MOSFETs and at relatively low frequencies. Furthermore, the leg functions as a synchronous boost with minimal conduction loss. The low volt-seconds figure across the inductor means that this component and the EMI filter can be made materially smaller than those in standard two-level converters.

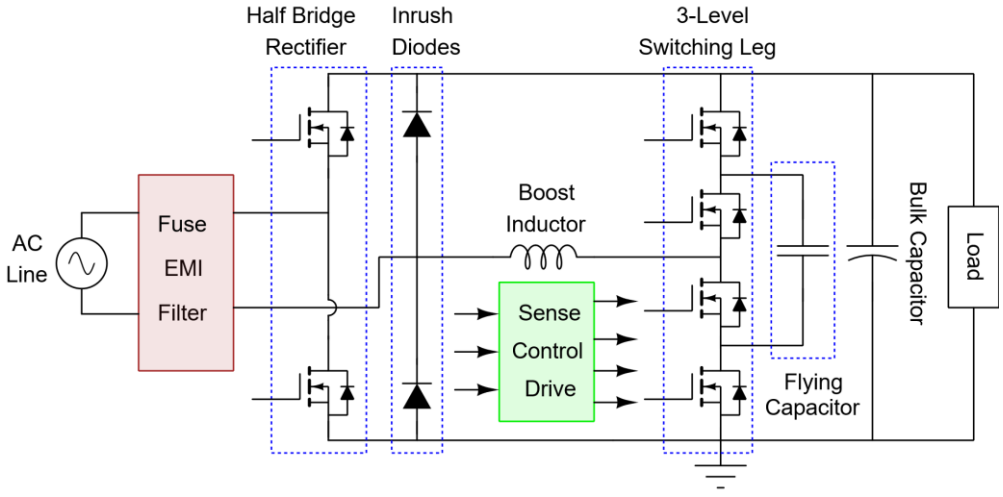

Figure 1 – An example of the multi-level conversion leg as used in PFC applications

Usage of the multilevel conversion leg as exemplified in Figure 1 is well suited to a wide range of deployments in power conversion. Implementation involving various power switches of different types and their control drive companions can be greatly simplified by modularizing the core multi-level power and control circuitry as shown in Figure 2.

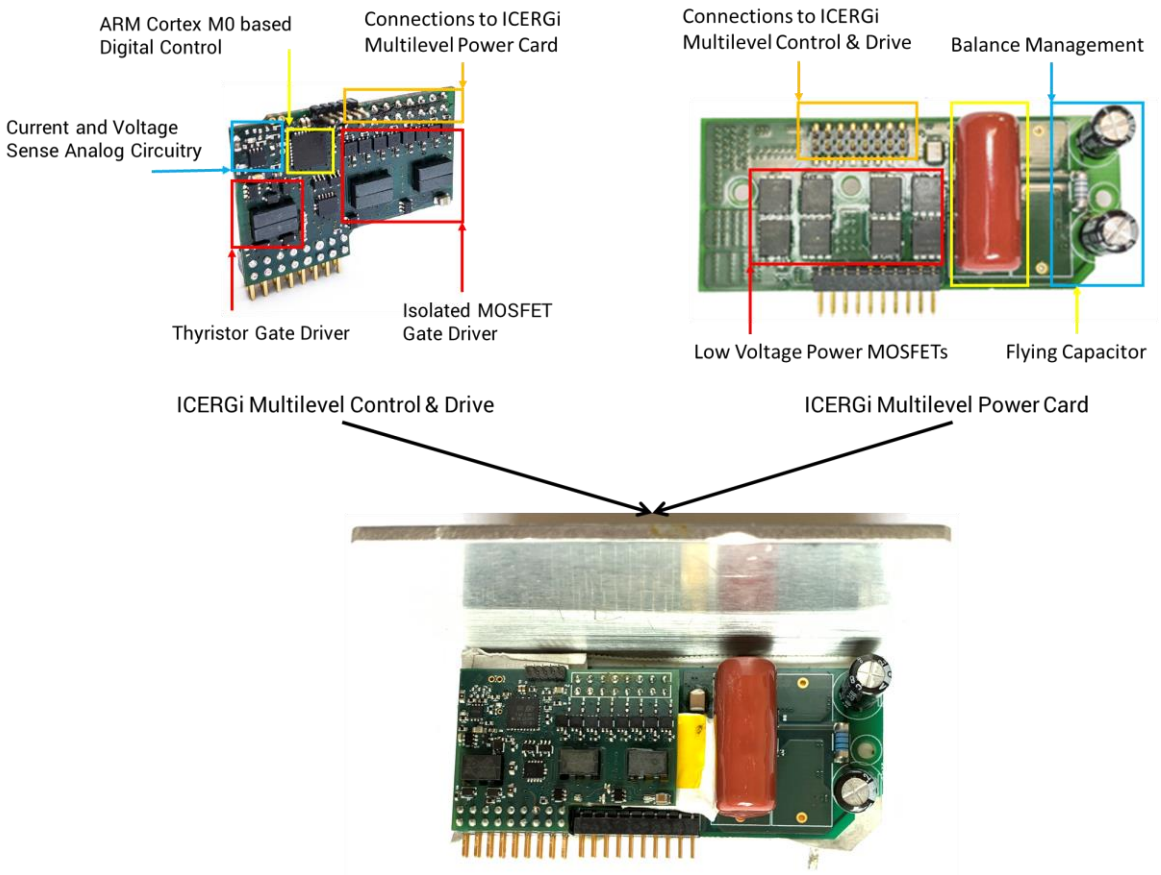

Figure 2 – Overall module with software-definable functionality

The structure of the module involves

- ICERGi Multilevel Power Card having a number of imbricated switching cells and a flying capacitor for voltage sharing. Each imbricated cell consists of two MOSFET/GaN switches driven in a complementary manner. The power card also houses proprietary circuitry designed to initialize the flying capacitor and enforce voltage balance.
- ICERGi Multilevel Control & Drive Card having both analogue and digital circuits dedicated for various functionality including driving and controlling low voltage MOSFETs in the power card, sensing voltage and current for control and protection, providing the necessary communications and control interfaces to additional stages, and many others.

This module can then be a very versatile hardware building block for implementation of functionality such as

- Front-end PFC stage of telecom rectifiers/standard switched mode power supplies
- Bidirectional PFC/Grid-tied Inverter
- Advanced Inverter with an ability to manage non-unity power factors and allow such stages to function as reactive compensators
- Synchronous buck/boost converters for battery and photovoltaic deployments
- Active-filter stages for use in shunt power-factor correction and in interfacing between photovoltaic converters and inverter output stages

- Many others

Some deployments are exemplified in Figure 3a-3d.

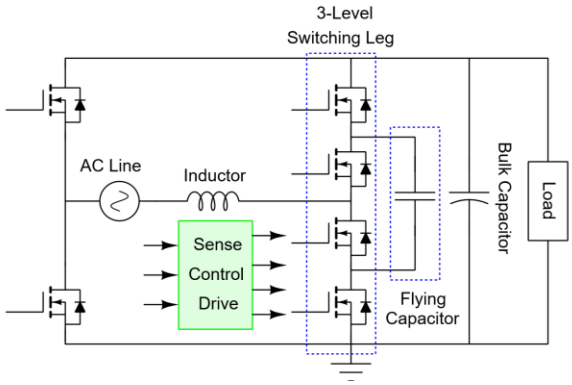

Figure 3a – Bidirectional PFC/Grid-tied Inverter

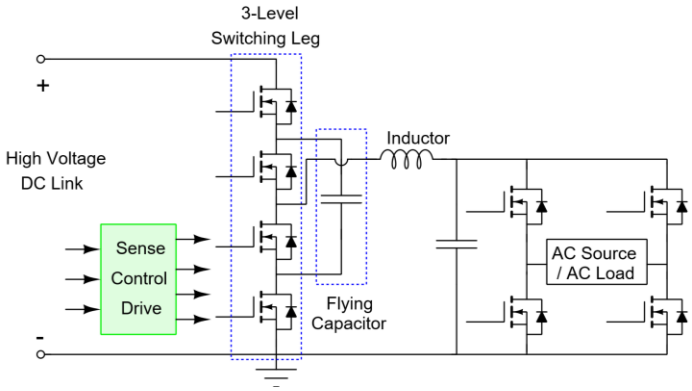

Figure 3b – Advanced Inverter with grid support capabilities

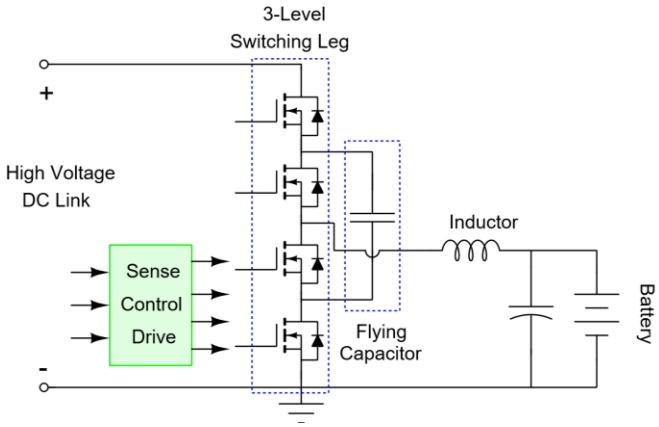

Figure 3c – Bidirectional synchronous buck for battery charger

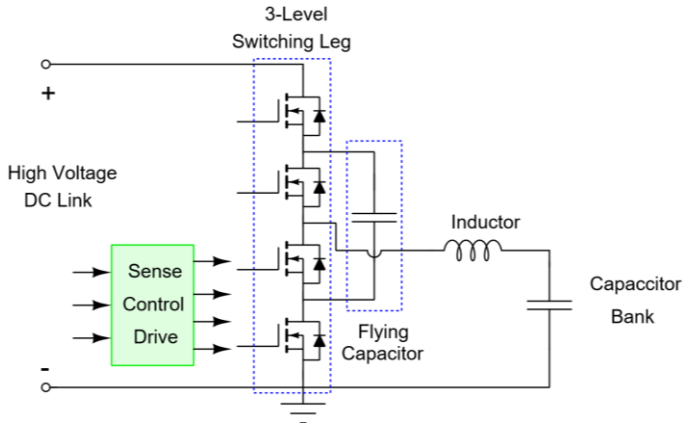

Figure 3d – Shunt active filter

3. Summary

Commonality in hardware building blocks is very valuable in limiting the range of assemblies to be handled and in allowing an optimised design to be leveraged across many usage environments. Designing such versatile hardware modules with software-programmable functionality is key and this has been effected in the range of products offered by ICERGi.

References

[1] T. T. Vu and E. Mickus, "99% Efficiency 3-Level Bridgeless Totem-pole PFC Implementation with Low-voltage Silicon at Low Cost," IEEE Applied Power Electron. Conf. and Expo. (APEC), Mar. 2019, pp. 2077-2083

Revision History

Date	Version	Changes
05-12-2015	1.0	First release
11-08-2019	1.1	Updated Figures 1, 2, and 3 Updated text for Section 1 & 2 Add brief description of the power module in Section 2 Updated references