Advanced Multilevel Topologies: A Technological Breakthrough?

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Before we start to discuss the potential of advanced multilevel topologies, let's have a look at the history of power electronics research topics. Topics regularly pop up and promise to solve all the problems you have never before heard of. The main challenge seems to identify the really important information and the right ideas for a sustainable development process. But could a technological break-through, based on the multilevel approach, really be possible?

We have heard about so many different solutions over the last years. There was a time when figures about potential power density up to 100 kW per liter caused a massive investigation of matrix converter topologies. When you take a look at the programmes of recent power electronics conferences and search the web for real industrial applications, you will see that the focus on matrix converters research now seems to be over. This happened to a lot of promising power electronics research topics - only a minority of them advanced to real industrial products and applications.

Certainly, there is always the potential to optimise a technology for a special application but, in the end, the classical well-known technology together with the latest available components often provides the best cost-to-performance ratio. It seems to be true even for one of the current megatrends - the optimisation in direction of efficiency. Additional components, that you don't need and don't use for simple topologies, can't cause losses. Hopefully the power electronics expert will now realise that a higher grade of optimisation could potentially be reached if achieved on the next higher level of integration. Sometimes this can even cause new losses due to additional components or at least higher losses on single components than before.

Another very important topic these days is the handling of increasing voltage levels with power electronics. A promising development started with the appearance of the first wide band gap semiconductor devices (e.g. SiC). The classical Si- components seem to limit the increasing needs of application in the medium and high-voltage area such as traction and HV-DC power transmission.

Let us return to the subject of advanced multilevel topologies. Parallel to the as yet unsuccessful efforts to get SiC or Diamond-based semiconductors for high breakdown voltage up to 10kV, multilevel topologies have garnered the interest of the industry and have found their way into the first real applications. Dividing high-voltage into smaller voltage steps with the multilevel approach still allows for the use of classical silicon-based semiconductors in several high and medium voltage applications - like HV-DC power transmission or large drives.

It seems that the multilevel technology got lost in the shadow of the brilliant research on power semiconductors with high breakdown voltage. This allows a steady ongoing development in the direction of industrial needs. It may seem surprising that multilevel topologies are of interest even for the range of typical low-voltage applications (<1000V). While a lot of optimised switches (e.g. IGBT) are available, advanced multilevel topologies like the Modular Multilevel Converter (M2C) are starting to outperform the classical 2-level solutions with fewer losses and a higher virtual switching frequency. This is due primarily to the ability to use highly optimised 100V to 200V MOSFETs. The sum of losses caused by the low Rds-on is less than the losses caused by the classical saturation effect of IGBTs. In addition, the switching losses of a MOSFET-based multilevel solution will be much lower.

This takes us back to the aforementioned research on wide-band gap devices. An initial handicap of GaN power semiconductor was that they are suitable only for low-voltage applications but the combination of the right advanced multilevel topology together with GaN power semiconductors can totally change the situation. Consequentially the missing high-breakdown voltage capability from GaN semiconductors is losing its importance in comparison to the benefit of the lower Rds-on. A change of direction in power semiconductor devices research could even result.

What are the challenges for multilevel topologies towards increased acceptance? It might be the necessity for more than the classical 2 switches per phase-leg and the necessary additional control effort.

Comparing the development history of power electronics with that of embedded systems, we will realise that there was always a tendency for more complexity, additional functionality and switch functions in the typical microprocessor or microcontroller area (Moore's law). For a long time, more than 2 switches per phase leg was considered by power electronic engineers to be evil. A lot of developers fear the additional complexity and additional cost for components.

Now is the time to stop fearing a higher complexity and start the next chapter of more advanced power electronics, which could lead to a real technological breakthrough.

The European Center for Power Electronics will discuss the latest achievements of research and industrial applications in their upcoming ECPE workshop on "Advanced Multilevel Topologies" on September 28-29, 2010 in Västeras (Sweden). You are welcome to participate and identify the potential for your application and the future.

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