Higher Efficiency through Innovative Power Semiconductors

Renewable energies and transportation can benefit heavily from the application of innovative power semiconductors, as the keynotes and the best paper of PCIM 2009 have illustrated.

Benjamin Sahan (middle) from University of Kassel (Germany) was awarded with the BPA handed over by PCIM organiser Udo Weller (left) and PEE editor Achim Scharf

In December 2008, the European Union decided to launch the 'Renewable Energy Road Map', including the target of producing 20% of total EU energy consumption from renewable energy sources by 2020. The German BEE (Bundesverband Erneuerbare Energien) even announced a scenario in January 2009 with a share of 47% of renewable electrical energy for Germany by 2020. One important and increasing part of this renewable share will be photovoltaic (PV) power. PV has some special characteristics, which predestinate it to play a major role in the concert of different renewable energy sources. This issue was evaluated – using Germany as reference - by the study 'The Role of Solar Power Generation in Future Energy Provision Structures – What Value has Solar Power?'. The study provides evidence that wind and solar energy complement one another in an ideal way, because the solar peak production in summer correlates with the maximum wind power production in winter. This demonstrates the need of increasing solar energy capacity with more and more wind power plants being installed.

Solar energy will be one pillar of the energy supply of the future. Grid-connected photovoltaic systems will thus – according to EPIA's figures - generate more than 12% of the electrical energy by 2020. The maximum yield of a PV plant coincides with the peak of daily energy demand. Therefore, and due to the decentralised nature of PV energy, a large amount of PV power can be easily integrated into the grid without expensive measures such as additional transmission grid lines. However, in future power supply networks, renewable energy sources must be integrated into grid control. Consequently, solar inverters will have to be able to contribute to stabilising and supporting grid operation. Active power has to be limited when necessary, reactive power has to be provided on demand, and systems must not disconnect under failure conditions such as voltage dips.

Best paper on SiC and PV

The paper covering SiC and PV received the Best Paper Award. Power Electronics Europe has sponsored and handed over for the second time the Best Paper Award at the PCIM 2009 opening ceremony. The awardee will participate at PCIM China 2010 including flight and accomodation. The best paper has been selected by the PCIM Conference directors and the winner is Benjamin Sahan from University of Kassel (Germany) with the paper 'Photovoltaic converter topologies suitable for SiC-JFETs'.

Silicon Carbide (SiC) is characterised by electrical field strength almost nine times higher than normal Si, allowing the design of semiconductor devices with very thin drift layers and, as a consequence, low on-state resistance and reduced switching losses. In other words, such characteristics can be translated into the possibility of operating at higher blocking voltages with reduced losses. Increased reliability due to its robustness, especially against temperature and cosmic radiation-induced failure are additional highlights of this new technology.

These characteristics are especially interesting when applied in photovoltaic converters. There, efficiency is still one of the main market drivers in the industry. Today, enhancing the PV inverter efficiency by 1% could yield up to 45€/kWp…97€/kWp additional profit after 10 years of operation. For this reason, PV inverter technology rapidly improved during the last

decade, and a peak efficiency of 99% will soon be achieved. From that point on, further increase of efficiency is no longer cost-effective. "As a future trend, SiC offers the possibility of operating at higher switching frequencies without significant prejudice on the efficiency, which leads to the possibility of reducing the size of passive components and consequently the cost and volume of the circuit", Sahan stated.

SiC for PV

In order to achieve the 12% share of electrical energy, the cost of PV energy must decrease significantly within the next decade. One approach for price reduction of PV generated electrical energy is to maximise the PV system efficiency. In the last 20 years, the efficiency of PV inverters increased from 91% up to 98% today, which reduces the necessary generator dimensions for the same AC output power by 7.5%. "With new semiconductors (for example SiC), the efficiency may be increased to 99%. This will reduce not only the PV generator dimensions for a given rated power of the PV system, but also lead to a higher power density and therefore to less mechanical equipment and thus reduce costs again. Therefore, increasing efficiency is a constant challenge in the field of PV inverter development", stated Andreas Falk from SMA Solar Technologie AG/Germany in his keynote 'Efficiency and Grid Compatibility of Photovoltaic Inverters – State of the Art and Future Trends'.

The progress from design to efficiency and other trends in PV inverters was driven by significant improvements in the field of semiconductors, magnetic components and controller hardware in the past, and will initiate further developments in various fields of power electronics in the future. PV inverters cover a significant market share of the power electronics industry today and will increase this share until 2020.

"With new semiconductors such as SiC, the efficiency of photovoltaic converters may be increased to 99%", stated Andreas Falk from SMA Solar Technologie

SiC for railways

Silicon Carbide will also become the semiconductor material of choice, as Michael Fröhlich from Bombardier Transportation in Mannheim/Germany in his keynote 'Technology trends in railway traction' pointed out.

Energy efficiency is a major strategic asset of modern traction and auxiliary equipment. Increasing energy prices will lead to even higher focus on overall energy efficiency of the railway. Key elements of further energy efficiency improvement are energy storage devices and their optimal use in the traction system, permanent magnet motors and, eventually, the use of medium frequency conversion from catenary voltage to traction system voltage levels also. In addition, driving style management systems support the efficient use of the trains during service operation.

"Technology trends in component basis such as semiconductors with Silicon Carbide in the long-term, or IGBTs with higher junction temperatures in the short-term, could be used for cost, size, and weight reduction", pointed out Michael Fröhlich from Bombardier Transportation

The evolution from GTO to IGBT technology was one of the major steps leading to lower costs, reduced weight and size. On the semiconductor side, this trend is still ongoing. From a long-term perspective, the introduction of SiC will lead to a huge step in higher integration levels. The very high junction temperatures of SiC elements will lead to a huge technology step in the cooling area. Considerably higher temperature differences between heatsink and ambient temperature will lead to much higher power densities. On the other hand, the higher temperatures inside the converter will require technology changes on all inverter components. For example, Gate Drive Units will have to operate reliably in much higher temperatures. The same goes for all converter components such as capacitors or busbars.

Already today, IGBTs with higher junction temperatures of 150 to 175°C are in the introduction phase. These IGBTs will already allow higher output power in actual converter dimensions.

"Technology trends in component basis such as semiconductors with Silicon Carbide in the long-term, or IGBTs with higher junction temperatures in the short-term, could be used for cost, size, and weight reduction. Size and weight reduction on traction equipment enables new vehicle concepts such as hybrid trains, which require heavy components such as transformers and diesel power packs on board one train", Fröhlich said.

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