PV System Technology Considerations for PV-Powered Passenger Vehicles

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Main Authors: K. Bittkau, L. H. Sloof-Hoek, A. Faes, B. Chambion, K. Araki.
Editor: K. Bittkau, Forschungszentrum Jülich, Germany

Executive Summary

This report provides a comprehensive overview of Vehicle Integrated Photovoltaic (VIPV) systems, focusing on their technological considerations, challenges, and potential applications in the automotive industry. The report covers various aspects of VIPV, including curvature, aesthetics, weight impact, compliance, and safety.

- **Curvature**: The integration of photovoltaic (PV) modules onto curved vehicle surfaces presents unique challenges. Researchers have explored various manufacturing techniques for both Vehicle Applied PV (VAPV) and Vehicle Integrated PV (VIPV). The report discusses the mechanical behavior of PV cells under double curvature, providing insights into the limits of cell bending to avoid cracks and electrical losses. The impact of curvature on PV performance and yield is also examined, highlighting the need for optimized electrical topologies in curved modules.
- **Aesthetics**: The report emphasizes the importance of aesthetics in VIPV applications, particularly color and surface finish. Various coloring techniques for different PV technologies are presented, including coloring of rear-side materials, solar cells, front encapsulants, and front materials. The report also discusses the challenges of color reproducibility and the demand for specific RAL colors in VIPV applications.
- **Weight Impact**: The additional weight of onboard PV systems is a critical factor in evaluating the energy benefits of PV-powered vehicles. The report presents a methodology to assess the impact of PV weight on the energy balance of electric vehicles, introducing the concept of a yield factor. Case studies involving different PV technologies and vehicle models demonstrate that the impact of PV weight is significant but can be offset by energy yield during parking phases.
- **Compliance and Safety**: The report outlines the current lack of dedicated standards for VIPV and addresses a safety qualification program based on existing PV and automotive standards. This program combines elements from IEC 61730-2:2016 and ISO 16750, along with additional tests specific to VIPV applications. The report also discusses recent updates to relevant standards and their implications for VIPV testing.
- **Testing Considerations**: Special testing requirements for curved PV modules are highlighted, emphasizing the need for reproducible testing methods. The report presents findings from international round-robin projects involving testing laboratories and research institutes, revealing challenges in measuring curved modules and the importance of considering indoor test results versus outdoor performance for VIPV products.

- **Toxic Materials and Vibration Robustness**: The report briefly mentions the potential use of toxic materials in VIPV systems and the importance of considering political regulations and recyclability. Vibration robustness is identified as a significant risk for long-term reliability, with the report discussing the limitations of current damping materials in the frequency ranges relevant to vehicle applications.

Key Takeaways:

- VIPV technology presents unique challenges in terms of curvature, aesthetics, and weight impact that require careful consideration during design and implementation.
- Standardization efforts are ongoing to develop comprehensive testing and safety qualification programs specific to VIPV applications.
- The energy balance of PV-powered vehicles depends on various factors, including PV technology, vehicle type, and usage patterns.
- Aesthetic considerations, particularly color and surface finish, play a crucial role in the acceptance and integration of VIPV systems.
- Special testing methods and considerations are necessary for curved PV modules to ensure accurate performance evaluation and long-term reliability.

Future Outlook:

As VIPV technology continues to evolve, further research and development are needed to address the challenges identified in this report. Standardization efforts, improved testing methodologies, and advancements in PV technologies tailored for vehicle integration will be crucial in realizing the full potential of VIPV systems in the automotive industry. In particular, road authorities have their own quality tests for safety requirements. VIPV performance and energy yield evaluation require much more input data, including the commute pattern, without having any standard that allows a comparison between different VIPV systems.