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# Editorial: Smart solar photovoltaic inverters with grid-supportive services

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Editorial on the Research Topic
Smart solar photovoltaic inverters with grid-supportive services

This Research Topic on *Smart Solar Photovoltaic Inverters with Grid-Supportive Services* includes eight articles. In bulk power systems, synchronous generators (SGs) regulate the grid frequency and voltages. The per-unit kinetic energy (defined as inertia) of SGs plays a vital role in the regulation of frequency. Driven by the desire for clean electricity, modern grids are undergoing an energy transition from fossil fuels to renewable sources. However, renewable energy sources require power electronics, e.g., PV inverters, to feed into the grid. Therefore, inverters need to gradually replace SGs. However, unlike SGs, PV inverters only track maximum power points and feature no massive rotational parts and no inertia. In consequence, the phase-out of fossil fuels inevitably poses challenges in the form of inertia shortages and grid formation. The remaining SGs are vulnerable to frequency disturbances, leading to cascading failures and/or even blackouts. Increasing spinning generation reserve suffers from high operating costs and low efficiency. Existing grid-tied inverters possess the potential for grid support and challenge mitigation. On top of typical SG functionalities, stand-alone ESSs benefit from control flexibility, thereby having the potential for power quality conditioning (such as reactive power compensation and harmonic filtering), meaning they provide add-on benefits.

This Research Topic aims to address the design and control challenges of smart PV inverters that support modern power systems, laying the foundation for future power systems with 100% renewable energies. The eight papers mainly focus on the control and design of PV inverters with grid-supportive services.

Meng et al. proposes a three-input central capacitor (TICC) dc/dc converter for a high voltage PV system, where four low-rating cascaded buck-boost converters connect to the series-connected three low-voltage PV arrays and two capacitors, realizing the maximum power point tracking (MPPT) independently.

Meng and Fang proposes a novel *LCL*-filtered half-bridge DSTATCOM topology, where the conventional filter capacitor of an *LCL* filter is replaced by DC-link capacitors with relatively larger capacitances. In consequence, the grid side inductance can be dramatically reduced from the order of millihenry to several microhenrys. Furthermore, the current stresses of semiconductor switches can be decreased. This paper also presents a power flow analysis and filter design procedure, demonstrating that a constant DC-link voltage can always be maintained and that the voltage variation across each capacitor can be well-regulated with properly designed filters and controllers.

Zhang et al. proposes novel lattice power grids that combine the advantages of multilevel converters and power grids, thereby allowing both serial and parallel connectivity with modularity and scalability. In addition, control and optimization algorithms for lattice power grids by use of graph theory are introduced. The study also proposes control and optimization algorithms for lattice power grids by use of graph theory, detailing control and optimization methodologies for square lattice power grids.

Shi and Zhao proposes a passivity enhancement strategy for the grid-connected inverter system *via* the adaptive active damper. Furthermore, the admittances of the grid-connected inverter system with the active damper are derived, and the real parts of the admittances of the whole system have been calculated.

He et al. analyzes the transient stability of PV generators under large disturbances and proposes a variable parameter control strategy to suppress the transient instability. The transient stability of the PV generators is analyzed through the proposed power-voltage evolution curve. The study finds that the PV side easily suffered from undervoltage faults during the transient process, which will cause the instability of the system. Based on the revealed unstable mechanism, a variable parameter control is proposed to enhance the transient stability of PV generators.

Feng et al. studies three typical modulation methods in DAB converters. These include traditional single-phase-shift (SPS), dual-phase-shift (DPS), and the emerging cooperative triple-phase-shift (CTPS) modulation. The study reports an interesting phenomenon, showing that the open-loop impedances of SPS-DAB and DPS-DAB converters present the characteristics of the parallel-connected inductor and capacitor, while the open-loop impedance of the CTPS-DAB converter presents the resistor characteristics.

Feng et al. introduces the impedance models of DAB converters. Based on the developed impedance models, the stability of the DAB-based two-stage AC-DC-DC converters is analyzed. The impact of the DAB converter circuit parameters on the stability of the two-stage AC-DC-DC converters are comprehensively revealed by the Bode and Nyquist plots.

Deng and Fang **addresses concerns about** inertia by exploring distributed virtual inertia (DVI) from grid-tied power converters. DVI is emerging as an attractive solution and proposes flexible distributed virtual inertia delivered by grid-forming converters (GFMCs) without additional energy storage units. This study reveals that virtual inertia control might cause stability problems. Through the derived state-space model and sensitivity analysis, the mechanism of instability is disclosed. Although droop control may stabilize converters, it inevitably necessitates extra energy storage and is hence not cost-effective. Instead, a lead compensator, together with its design procedure, is proposed.

The contributions to this Research Topic involve a marriage of power electronics and power systems, which together create a complementary technological roadmap to developing electronic power systems in the future.

## Author contributions

JF has made a substantial contribution to this work. All the authors agree with the publication of this work.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note