Simplified 800V Power Supply Architecture for 99%+ Efficient Data Centers

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***Abstract* – In this study, a comparative analysis of 800V power supply unit (PSU) architectures for MW-scale data centers is examined, for the AC power delivery to the 800V DC bus. Conventional PSU architectures typically rely on a two-stage power conversion chain, comprising an AC–DC front-end followed by an isolated DC–DC converter. While this approach provides galvanic isolation and voltage regulation, it incurs additional conversion losses, component count, and cooling requirements.**

Power conversion architectures with reduced isolation stages have matured through extensive deployment in renewable energy systems, demonstrating their technical feasibility and reliability. Inspired by the success of renewable solar photovoltaic reduced-isolation architectures, the proposed single-stage PSU eliminates an intermediate power conversion stage, achieving more than a 1% improvement in power conversion efficiency while reducing component count, cooling requirements, and increasing power density.

The proposed AC-DC single-stage system is based on ZVS technology which further increased the conversion efficiency and its associated benefits. This study explores the technical considerations for deploying single-stage PSU architecture in next-generation AI datacenters, with particular emphasis on efficiency and fault management.

Keywords—Power supply unit (PSU), three-phase rectifier, 800V architecture, high-efficiency power conversion, zero voltage switching (ZVS), DC distribution.

I. INTRODUCTION

System efficiency is a key consideration in high-power distribution systems because reduced conversion and conduction losses directly translate into lower infrastructure requirements and operating costs. For the same copper cross-sectional area, an 800 Vdc distribution system can deliver approximately 157% more power compared with a conventional 415 Vac three-phase distribution system (L1/L2/L3/PE) due to the higher utilization of conductor capacity and reduced current levels [1]. This reduction in current enables smaller conductors, lower copper consumption, reduced resistive losses, and improved thermal performance, ultimately contributing to lower capital and operational costs.

The 800 Vdc bus has emerged as the preferred voltage platform for high-power applications such as DC fast charging infrastructure, battery energy storage systems, renewable energy power conversion, and next-generation electric vehicles. The rapid growth of these industries has accelerated the development of a mature supply chain of 800V components, including SiC power semiconductors, magnetics, capacitors, connectors, protection devices, and control technologies. Leveraging this established technology ecosystem enables AI datacenters to benefit from proven, high-efficiency power conversion solutions while reducing development risk, system cost, and time to market.

Fig. 1 shows a simplified representation of 800V distribution architecture option for datacenters, comprised of line frequency transformer (LFT) to step down from a wide medium voltage (MV) range of (10 … 35) kV to (400 … 480) Vac, followed by PSU and IT racks.

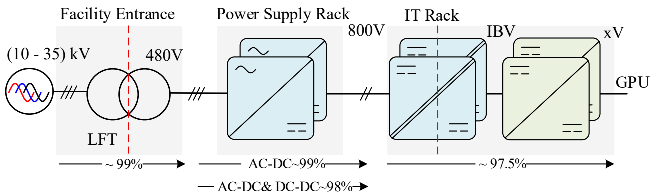

Fig. 1. Simplified representation of 800V PSU architectures with estimated efficiencies of a) 98% with AC-DC & DC-DC two-stage conversion and b) 99% AC-DC single-stage conversion.

This study analyses the PSU architectures, as shown simplified in Fig. 1. The main observations of this study are as follows:

1) A comparative analysis that aims to identify the advantages and limitations of PSU topologies in sidecar data centers.

2) System architecture with optimized galvanic isolation: the proposed 800 V power distribution architecture retains two essential galvanic isolation barriers: the line-frequency transformer (LFT) located at the facility entrance for utility isolation and voltage transformation, and the isolated DC–DC converter at the IT rack level for equipment safety, fault containment, and compliance with electrical safety requirements.

Power conversion architectures with reduced galvanic isolation stages have been successfully demonstrated in photovoltaic (PV) energy systems and are now widely deployed in commercial applications [2], [3], [4].

3) High-efficiency PSU enabled by Zero-Voltage Switching (ZVS): The proposed PSU leverages ZVS technology to significantly reduce switching losses, improve power conversion efficiency, and increase power density. Importantly, ZVS is topology-independent and can be implemented in both conventional two-stage and proposed single-stage PSU architectures, enabling high-efficiency operation across a wide load range while reducing thermal management requirements and cooling costs.

An overview and comparative analysis of the 800V PSU architectures are presented in Section II. Section III introduces ZVS PCS1000, followed by the concluding remarks.

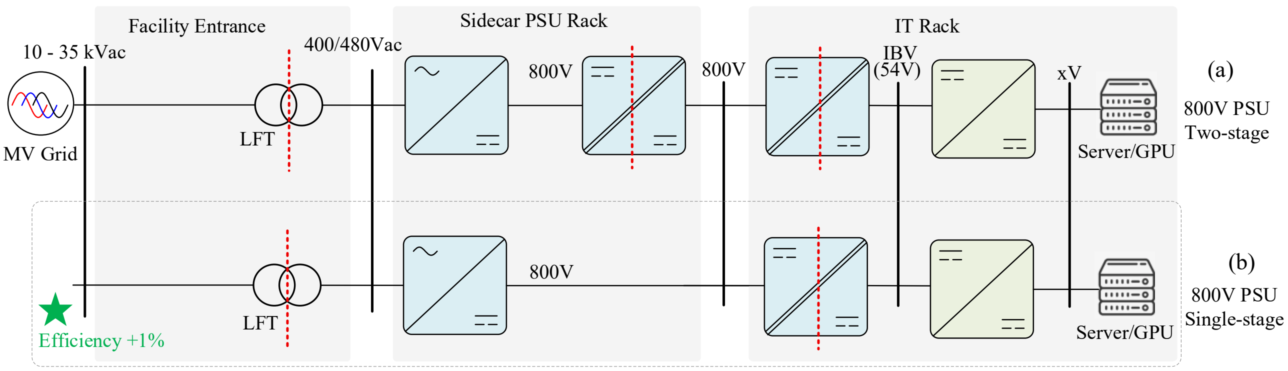

Fig. 2. Datacenter PSU sidecar architectures: a) Two-stage PSU and b) Single-stage PSU.

PSU architecture	800V Two-stage	800V Single-stage
AC to DC total layers of galvanic isolation	3	2
PSU typical efficiency	98%	99% (*)
Cooling requirements	Moderate	Low
Cost	Moderate	Low
Reliability	Moderate	Highest (lower number of components)
Protection complexity	Moderate	High
Arc flash risk	Moderate	High
Insulation stress	Moderate	Moderate
Spacings requirements	Moderate	High
Circulating current risk	Low	Medium
Power density (including transformers)	High	High

(*) Note: 99.2% can be achieved using ZVS inverter topology and control.

Table I. PSU architecture comparisons.

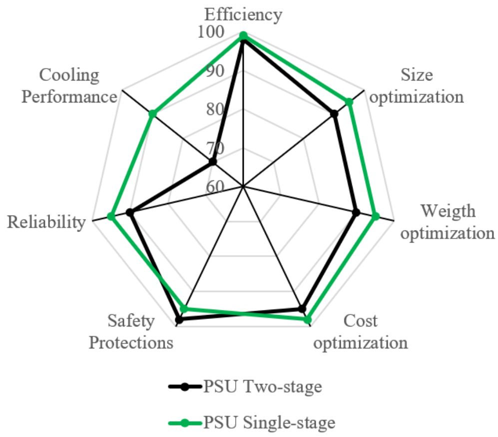

Fig. 3. Estimated Performance Comparison of Key Parameters.

II. Review of 800V PSU Architecture Comparisons

Fig. 2 presents two 800 V power distribution architectures for supplying power from the utility grid to the IT rack. The architectures differ in the number of power conversion stages and galvanic isolation barriers, leading to varying levels of efficiency, component count, protection requirements, and implementation complexity.

The power architecture shown are: A) Two-stage PSU, B) Single-stage PSU and C) SST PSU.

A. Two-stage PSU

The two-stage PSU architecture is characterized by three galvanic isolation barriers, provided by the line-frequency transformer (LFT), the sidecar isolated DC-DC converter, and the IT rack isolated DC-DC converter.

The two-stage architecture employs a dual-stage PSU conversion approach consisting of an AC-DC stage (e.g., single-phase PFC) followed by an isolated DC-DC converter (e.g., LLC), similar to the building-block architectures widely adopted in previous 400V/48 V power conversion systems. However, single-phase PFC converters present several limitations:

1) Significant twice-line-frequency ripple power, requiring large DC-link capacitors. In many cases, electrolytic capacitors are used, negatively affecting converter lifetime and reliability.

2) The ripple power introduces noticeable DC-link voltage fluctuations.

3) The voltage regulation bandwidth is limited, resulting in slower dynamic response and requiring a wider DC-link voltage tolerance range.

4) During PSU operation and servicing, grid phase imbalance can occur, leading to oversized switchgear requirements.

To address these limitations, an additional isolated DC-DC conversion stage, such as an LLC is commonly incorporated using a 1:1 conversion ratio (800 V to 800 V). Furthermore, galvanic isolation offers several benefits, including simplified parallel PSU operation, elimination of circulating currents, and potentially reduced spacing requirements due to lower transient overvoltages.

Conventional two-stage PSU architectures are primarily designed for unidirectional power flow from the utility grid to the IT load. As AI datacenters evolve into active participants in future smart grids, these architectures may limit the implementation of grid-supportive functionalities such as bidirectional power flow for demand response.

B. Single-stage PSU

Reduced isolation-stage architectures have already been successfully implemented in renewable energy systems.
In particular, transformerless solar converters have been widely deployed worldwide. The selected single-stage architecture eliminates the intermediate 800 V-to-800 V isolated DC-DC converter, while maintaining two overall

system galvanic isolation through the MV-LV transformer and the isolated DC-DC converter at the IT rack level.

A comparative assessment of the corresponding 800 V sidecar power rack architectures is provided in Table I.

Fig. 3 presents an estimated system-level comparison of key performance metrics. Single-stage architecture provides a more efficient and simplified power delivery solution, outperforming the conventional two-stage topology by reducing conversion losses, hardware complexity, and thermal management requirements.

In summary, the analysis indicates that the simplified single-stage PSU architecture offers several advantages over the alternative solutions:

1. Higher efficiency: Improved power conversion efficiency enhances energy utilization and lowers overall energy consumption. The reduced power losses also decrease cooling requirements, contributing to lower facility capital costs.
2. Improved reliability and lower cost: By reducing the number of power conversion stages and associated components, the single-stage PSU architecture achieves a lower component count, which improves system reliability, and reduces overall system cost.
3. Superior thermal management with lower operating expenses due to reduced losses generated during system operation.
4. Built-in bidirectional power conversion without additional cost for future grid supportive functionalities.

III. 800V ZVS PSU Platform

Fig. 4 presents the proposed bidirectional AC–DC power conversion (480Vac-800Vdc) platform employing high-efficiency ZVS technology. The platform supports built-in bidirectional power flow and integrates AC- and DC-side disconnects, protection functions, pre-charge circuitry, and EMI filtering to ensure safe and reliable operation. It is designed to meet the safety requirements of IEC/UL 62368-1 and the grid interconnection requirements of UL 1741, making it suitable for high-power 800 Vdc applications, including AI datacenters, energy storage systems, and EV charging infrastructure.

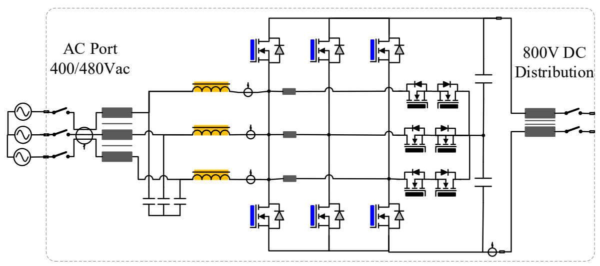

Fig. 4. Simplified AC-DC bidirectional single-stage PSU architecture.

Fig. 5 shows the 250 kW bidirectional AC-DC ZVS power converter platform designed with an integrated liquid-cooling system. As power density and conversion efficiency requirements continue to increase in next-generation AI datacenters, effective thermal management becomes a critical design consideration.

Fig. 5. Single-stage 250kW ZVS PSU form factor: 19" rack mount, liquid-cooled platform, designed by Hillcrest Energy Technologies Ltd.

Compared with conventional air cooling, liquid cooling provides significantly higher heat transfer capability by directly absorbing and transporting thermal energy away from high-power components. Coolants such as water-glycol mixtures offer substantially higher thermal conductivity and heat capacity than air, enabling more efficient removal of semiconductor switching losses, magnetic component losses, and other thermal hot spots.

The liquid-cooled platform enables higher power density, improved thermal uniformity, reduced cooling infrastructure requirements, and more compact converter packaging. This approach supports reliable operation of high-power conversion systems while maintaining the efficiency, scalability, and form-factor requirements of future 800 Vdc power architectures for AI datacenters and other high-performance electrification applications.

IV. Conclusion

This paper presented a next-generation PSU architecture designed to simplify the power delivery path from the AC grid to high-performance AI computing loads. By reducing the number of conversion stages, the proposed approach achieves greater than 1% efficiency improvement while reducing hardware complexity, cooling requirements, and overall system cost. The architecture preserves two essential galvanic isolation barriers between the MV grid interface and the AI load to ensure safety, fault containment, and compliance with applicable standards. In addition, the implementation of ZVS power conversion technology further enhances system performance by minimizing switching losses, reducing semiconductor junction temperatures, and decreasing thermal cycling stress. These combined benefits improve efficiency, power density, reliability, and lifetime, positioning the PCS1000 platform as a scalable solution for future high-power AI datacenter and DC electrification applications.

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