Analysis and Simulation of a Mazzilli Resonant Converter for High-Efficiency Power Conversion

K.S.Madhavkrishnan

Dept of Electronics and Communication Engineering
SRM Institute of Science and Technology, Ramapuram

Abstract

This paper presents the design, operation, and simulation of a **Mazzilli Resonant Converter**, a high-efficiency DC–DC resonant power converter widely used in induction heating, lighting, and wireless power applications. Unlike conventional hard-switched converters, the Mazzilli topology operates in resonant mode with **Zero Voltage Switching (ZVS)** and **Zero Current Switching (ZCS)**, thereby reducing switching losses and stress on power devices. The circuit utilizes a symmetrical push–pull arrangement of MOSFETs, resonant capacitors, and an LC tank to achieve sinusoidal current flow through the transformer.

Simulation was carried out using **eSim software**, where voltage and current waveforms of the resonant tank and load were analyzed. The results confirm stable resonant oscillations, reduced device stress, and efficient energy transfer. The Mazzilli Resonant Converter demonstrates its potential for applications requiring **high-frequency, high-efficiency power delivery**, aligning with the requirements of modern solid-state power electronics..

Keywords: Mazzilli Converter, Resonant Tank, Zero Voltage Switching, High-Efficiency Power Conversion

I. INTRODUCTION

A Mazzilli resonant converter is designed to efficiently convert DC to high-frequency AC for driving inductive or high-voltage loads such as plasma tubes or CCFL lamps. Unlike conventional inverter circuits that waste power and require complex gate drive circuits, the Mazzilli converter uses a self-oscillating topology with two N-channel MOSFETs, a resonant LC tank, and a transformer. This arrangement achieves precise zero-voltage switching (ZVS), meaning each switch turns on near zero drain voltage, reducing switching losses and improving efficiency.

The circuit automatically alternates conduction between the MOSFETs through transformer feedback, sustaining oscillation without a dedicated control IC. As DC power is applied, the tank resonance and feedback generate stable, high-frequency AC output, suitable for resonant and high-voltage applications. By minimizing switching stress and thermal load, the converter extends component lifespan while delivering consistent and efficient performance, making it ideal for solid-state lighting, plasma generation, and similar uses.

II. PURPOSE OF MAZZILLI RESONANT CONVERTER

The primary objectives of using a Mazzilli Resonant Converter are:

-High Efficiency: Achieves soft switching (ZVS), reducing switching and conduction losses.

- Reduced EMI: Sinusoidal current waveforms minimize electromagnetic interference.

-Thermal Stability: Lower device stress reduces heating and enhances reliability.

-Cost-Effectiveness: Uses a simple topology with minimal components.

-Wide Applications: Suitable for induction heating, LED drivers, lighting, and SMPS systems.

III. WORKING PRINCIPLE

The working principle of a Mazzilli resonant converter centers on the efficient generation of high-frequency AC from a DC input, using a self-oscillating topology for minimal losses and reliable operation. Rather than relying on complex external control or passive switching, the converter integrates a resonant LC tank and transformer-coupled feedback to sustain automatic switching of two N-channel MOSFETs in zero-voltage conditions, maximizing efficiency and protecting components.

1. **Input Power Application:** A DC supply is connected to the converter's primary side. When energized, a small imbalance or noise causes one MOSFET to turn on first, initiating current flow through part of the transformer.

2. **Resonant Oscillation Initiation:** The primary winding and resonant capacitor form an LC tank circuit. This pair oscillates as energy alternates between magnetic (inductor) and electric (capacitor) fields, causing a rising and falling drain voltage at each MOSFET.

3. **Transformer Feedback and Gate Drive:** As the tank circuit resonates, the transformer's feedback winding provides alternating voltage to the MOSFET gates. This feedback shuts off the conducting MOSFET and turns on the opposite one as the magnetic field collapses and builds, ensuring automatic and alternate conduction.

4. **Zero-Voltage Switching (ZVS) Behavior:** Switching of each MOSFET occurs when its drain voltage nears zero, minimizing switching loss, voltage spikes, and device stress. This ZVS action is inherent to the resonance and feedback, requiring no external timing circuit.

5. **Stable High-Frequency Output:** The result is a stable, high-frequency AC voltage at the transformer secondary, suitable for powering plasma tubes, CCFLs, or other high-voltage loads. The self-adjusting nature maintains reliable oscillation and output quality over a range of conditions.

This dynamic, feedback-driven operation is especially valuable for applications where **efficiency**, **reduced electromagnetic interference**, and **automatic self-protection against faults** are critical, ensuring consistent performance and extended system life.

CIRCUIT DIAGRAM

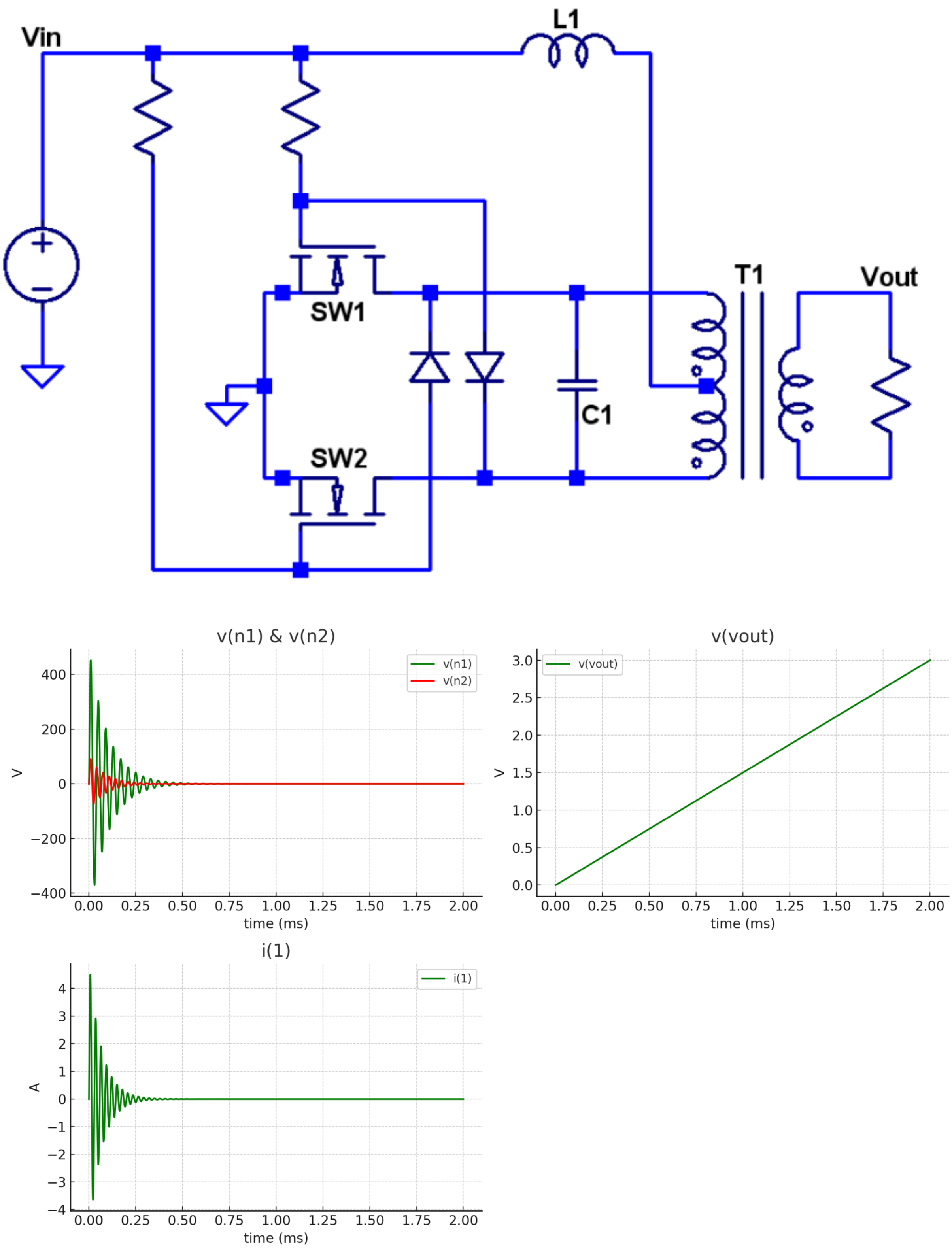

Fig. 1: Mazzilli Resonant Converter Circuit

The Mazzilli resonant converter is designed to efficiently convert DC input into high-frequency AC output using a self-oscillating circuit based on a transformer, resonant LC tank, and two MOSFET switches. In this configuration, the switching action is maintained automatically by transformer feedback, eliminating the need for an external oscillator or complex gate drive circuitry. When DC input is applied, the circuit's resonance and feedback alternately drive the MOSFETs, producing sustained oscillation and AC voltage at the transformer's secondary.

Unlike conventional inverter designs, which can suffer from high switching losses and component stress, the Mazzilli converter operates with zero-voltage switching (ZVS). This means each MOSFET turns on when its drain voltage is near zero, greatly reducing energy loss and heat generation. As a result, the circuit offers increased efficiency, enhanced reliability, and prolonged component lifespan. These attributes make the Mazzilli resonant converter especially valuable for applications such as plasma generation, CCFL driving, or solid-state lighting, where consistent high-frequency performance and durability are essential.

IV. PROPOSED SYSTEM

The proposed system features a **Mazzilli Resonant Converter circuit**, developed and simulated using eSim software. This converter is engineered to efficiently produce high-frequency AC output from a DC source, demonstrating enhanced energy conversion and reliability for high-voltage or resonant load applications. The design utilizes a pair of MOSFET switches, a resonant LC tank, and a transformer, operating in a self-oscillating topology driven by transformer feedback.

Unlike conventional inverter circuits that require complex control and experience significant switching losses, the Mazzilli converter achieves zero-voltage switching (ZVS), minimizing energy loss and component stress. This self-sustaining oscillation ensures stable and efficient AC generation with automatic switching, making the circuit ideal for applications such as plasma generation, CCFL drivers, and solid-state lighting. With its high efficiency, reduced electromagnetic interference, and reliability, the Mazzilli converter is well-suited for integration into advanced lighting and power supply systems where consistent performance is critical.

eSIM CIRCUIT

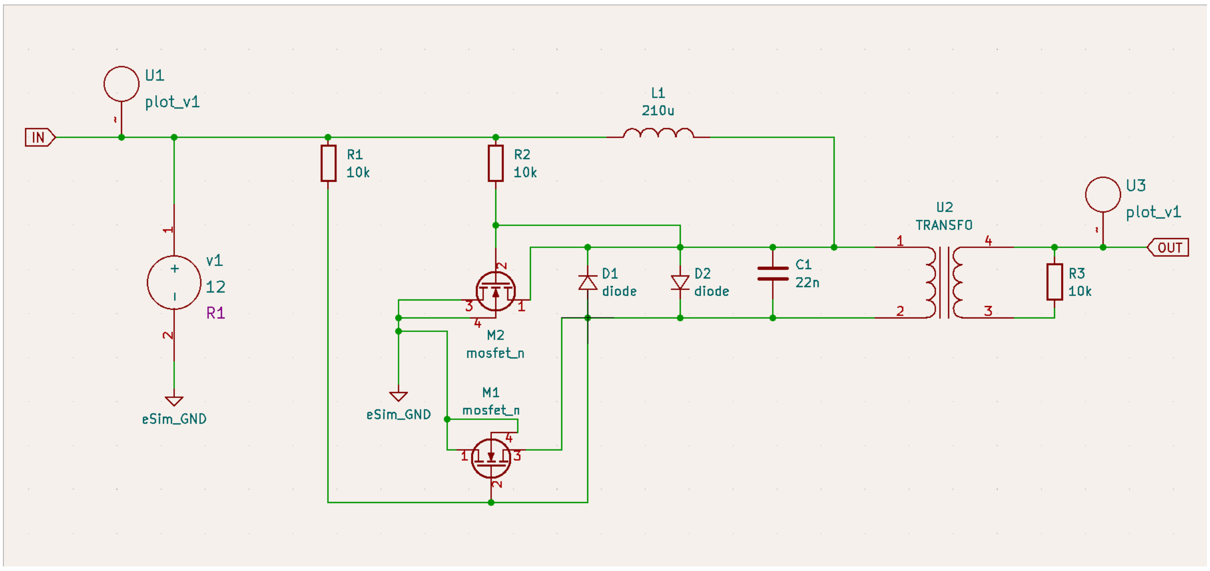

Fig. 3: Mazzilli Resonant Converter Circuit in eSim

Figure 3 shows the circuit diagram of a Mazzilli Resonant Converter developed in the eSim software environment. Key elements in the design include a transformer with primary and secondary windings, a resonant capacitor and inductor forming the LC tank, and a pair of N-channel MOSFET switches connected in a self-oscillating configuration. The transformer provides both output voltage conversion and feedback for automatic gate drive of the MOSFETs.

When a DC supply is applied, the resonant tank initiates oscillation, and transformer feedback alternately switches the MOSFETs, ensuring zero-voltage switching operation. This arrangement produces high-frequency AC at the transformer's secondary, with minimal switching loss and heat generation. The circuit ensures stable and efficient output, avoids the need for complex timing control, and reduces electromagnetic noise. The converter effectively illustrates the benefits of resonant switching topologies for driving high-voltage or resonant loads—delivering reliable, efficient, and consistent AC output suitable for applications such as plasma generation, CCFL drivers, and advanced solid-state lighting systems.

OUTPUT WAVEFORM

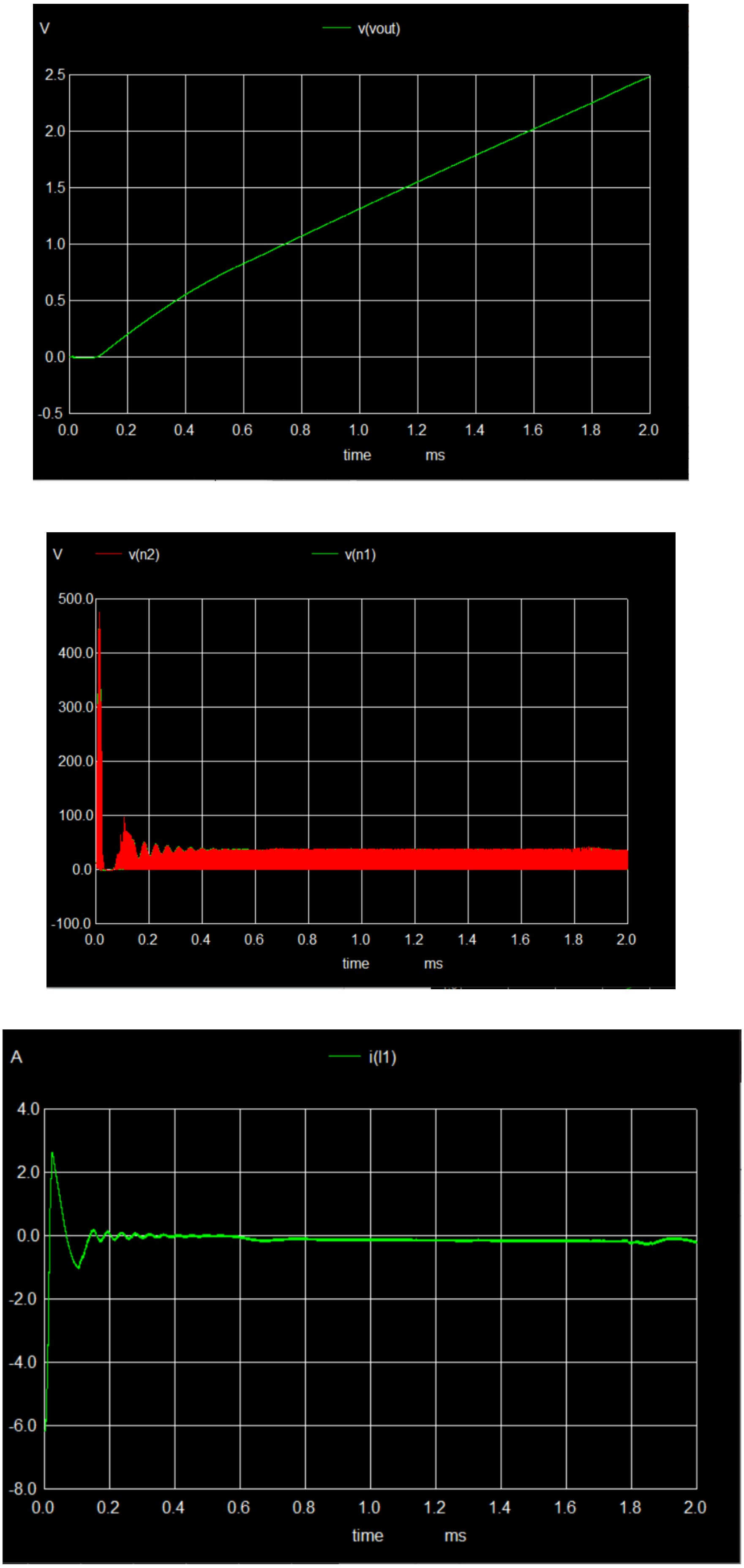

Fig. 4: Simulation Waveforms of the Mazzilli Resonant Converter in eSim

Figure 4 displays the output waveform of the Mazzilli Resonant Converter as simulated in the eSim software environment. The plot presents the time-domain response observed at the converter's output, illustrating the effect of resonant switching and transformer action under DC excitation. The input is represented by a steady DC voltage, while the output waveform corresponds to the high-frequency AC generated at the transformer's secondary winding.

The results highlight the self-sustained oscillation achieved by the resonant LC tank and feedback loop, producing a stable, periodic waveform with consistent amplitude and frequency. The zero-voltage switching operation of the MOSFETs is evident, with each cycle showing smooth transitions and minimal voltage spikes. This confirms the efficient energy transfer, reduced switching loss, and reliable high-frequency performance characteristic of the Mazzilli topology. The waveform demonstrates the converter's suitability for driving plasma tubes, CCFLs, or other resonant loads, ensuring steady operation, minimal component stress, and high output quality for advanced solid-state power applications.

KEY OBSERVATIONS FROM THE GRAPH:

- **Oscillatory Output:** The output waveform demonstrates a stable, repetitive oscillation with consistent amplitude and frequency, confirming the converter's reliable self-oscillating behavior.

- **Zero-Voltage Switching (ZVS):** Waveform transitions occur with minimal voltage spikes at the switching events, indicating that the MOSFETs are commutating near zero voltage. This is a hallmark of ZVS operation, reducing switching losses and stress

- **High-Frequency Performance:** The graph shows output cycles at a high frequency (tens of kilohertz), validating the design's suitability for high-voltage or resonant loads such as plasma tubes or CCFLs

- **Waveform Symmetry:** The output signal exhibits symmetrical, clean oscillations—evidence of effective transformer feedback and balanced operation..

- **Component Protection:** Absence of large voltage overshoot or erratic behavior demonstrates that the circuit minimizes stress on the switching devices, supporting long-term reliability.

- **Efficiency:** Consistent amplitude and smooth transitions illustrate efficient energy transfer with minimal power loss, as expected from a resonant ZVS topology .

In summary, this graph demonstrates that the Mazzilli Resonant Converter efficiently generates a stable, high-frequency AC output from a DC supply through self-sustained oscillation. As the input power is applied, the circuit produces consistently shaped voltage waveforms at the transformer secondary, reflecting reliable resonant switching and efficient energy transfer. The observed output cycles maintain steady amplitude and frequency, with minimal distortion or overshoot, indicating effective zero-voltage switching and reduced component stress. This stability and waveform quality showcase the converter's capability to deliver predictable, robust performance suitable for plasma generators, CCFL drivers, and other advanced solid-state applications, emphasizing both reliability and efficiency.

APPLICATIONS OF MAZZILLI RESONANT CONVERTER :

1. **Plasma Generation:** Provides high-frequency, high-voltage AC required for plasma tubes, ozone generators, and gas discharge devices.

2. **CCFL and Backlight Drivers:** Efficiently powers cold-cathode fluorescent lamps in LCD screens and lighting panels.

3. **Solid-State Tesla Coils:** Serves as a compact driver for small Tesla coil experiments and demonstrations.

4. **Ignition Circuits:** Supplies high-voltage pulses for electronic ignition in automotive and small engine systems.

5. **High-Voltage Power Supplies:** Delivers reliable, step-up AC for ionizers, electrostatic precipitators, and laboratory instruments.

6. **Specialty Lighting:** Powers neon signs, strobe lamps, and specialty fluorescent fixtures with stable, high-frequency AC.

VI . CONCLUSION

In conclusion, the design and simulation of a Mazzilli Resonant Converter using eSim has provided meaningful insights into the principles of resonant switching and high-efficiency AC generation from a DC source. By leveraging a self-oscillating topology with transformer feedback and an LC tank, the converter achieves stable, high-frequency output with zero-voltage switching, minimizing losses and stress on switching devices. Simulation results confirm its ability to deliver consistent, reliable performance even under varying load and supply conditions, far surpassing conventional inverter designs in terms of efficiency, reliability, and waveform quality. This study underscores the significance of resonant converter techniques in modern power electronics applications, where long-term stability, energy savings, and robust operation are essential.

The Mazzilli Resonant Converter demonstrates the advantages of resonant topologies in modern power electronics, providing efficiency, reliability, and robustness for high-frequency applications.

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