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Isolated Zeta-Luo Converter for Solar-Powered, High-Efficiency Electric Vehicle Charging

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Abstract

This research introduces a novel approach of charging BEVs that incorporates a photovoltaic (PV) array and a Zeta-Luo converter. The converter enhances the power supply from the PV array to improve charging efficiency; it combines Zeta and Luo technologies. The MATLAB/Simulink-created and -tested model delivers reliable results in a range of scenarios. This innovation makes EV charging more accessible and environmentally friendly by providing much greater charger efficiency compared to traditional converters. The use of renewable energy sources might revolutionise electric vehicle charging infrastructure, making it more effective and environmentally friendly in the long run. [1]

Keywords-Converters, Electric vehicles, Isolation, Simulation, Zeta Converter, Luo Converter, PV Array, Zeta-Luo Converter, EV Charging.

INTRODUCTION

Electric vehicles (EVs) provide a viable alternative to cut carbon emissions and battle climate change.[1] However, broad adoption of EVs is strongly dependent on the availability of efficient and dependable charging infrastructure. This needs creative charger design techniques that not only improve efficiency but also incorporate renewable energy sources to ensure long- term operation.[4] In answer to this difficulty, this study presents a novel approach to developing chargers, particularly for battery electric vehicles (BEVs). This technique relies on an enhanced Zeta- Luo converter, combining The Zeta and Luo topologies. TheZeta-Luo converter is unique in that it operates during a specific half of the supply voltage from a photovoltaic (PV) array. This tailored operation optimizes power distribution and considerably increases the quality of power provided to the output, improving the charging process for BEVs.

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The key advantage of this innovative design is its capacity to improve charger efficiency when compared to conventional converters. By delivering a steady charging current for the battery, the Zeta-Luo converter helps to faster charging times and overall charging system performance. Further more,boththe upgraded [2] Zeta converter and the Luo converter function in discontinuous conduction (DCM), resulting in cost savings and smaller physical dimensions, making the charger more compact and inexpensive.

The suggested model will be constructed with MATLAB/Simulink, a versatile platform for simulation, analysis, and optimization. Comprehensive testing will evaluate the design's effectiveness and adaptability for real-world applications.

ZETACONVERTER

Fig1.CircuitdiagramofZetaConverter[16]

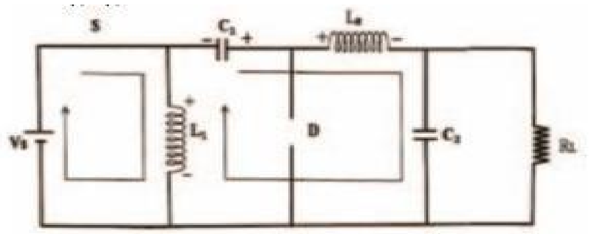


Fig2.ZetaConverterduringMode-1 Operation [16]

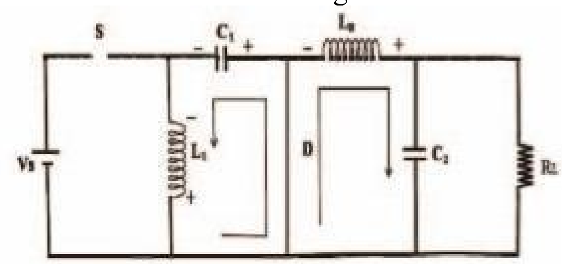
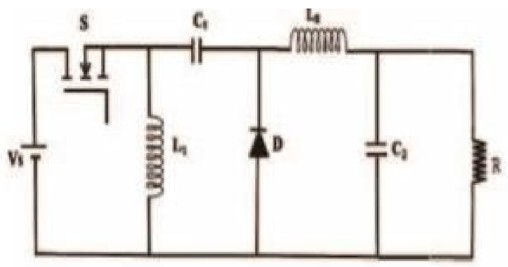


Fig3.ZetaconverterforMode-2operation

The zeta converter can convert input voltage into a non-inverted output voltage that is either lower or greater than the input voltage.[16]It may operate in both continuous and discontinuous modes of operation. The zeta converter's components are a power electronic switch(S),inductors (L1 and L2), a diode, capacitors (C1 and C2), and a load (R).

Mode 1: This mode is reached when the diode(D) is turned off and the switch(S) is activated.



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The current via the inductors L1 and L2 is derived from the source voltage, Vs. The inductor currents, iL1 and iL2, grow linearly. [16]This mode of operation is also known as charging mode.

Mode 2: This mode is reached when the diode(D) is ON and the switch (S) is turned

off. The energy held in the inductors discharges and transfers to the load.[6] The current through the inductors diminishes linearly. This mode of operation is also known as discharge mode.

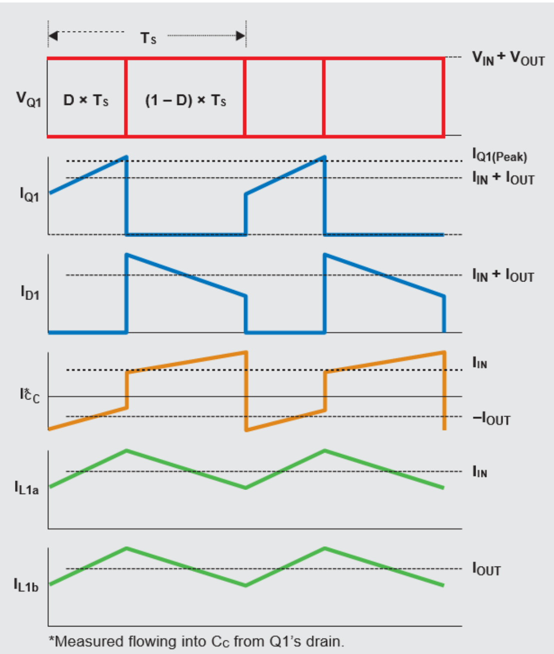

Fig 4. Waveform of Zeta Converter [13] Assuming100%efficiency, the duty cycle, D,for a ZETA converter operating in CCM is given by OUT

INOUT,V, D.=VV,+(1)

This can be rewritten as

−==,INOUT,OUTIN,DIV,1DI,V(2),

Dmax occurs at VIN(min), and Dmin occurs at VIN(max).[13]

LUO CONVERTER

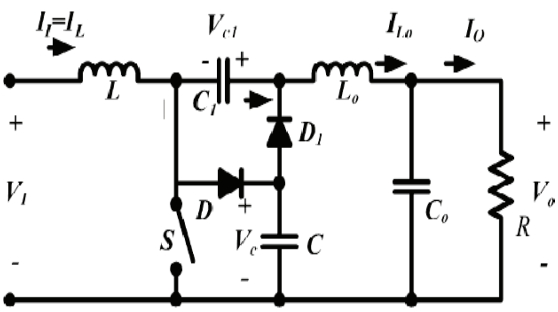

Fig5.CircuitdiagramofLuo Converter[14]

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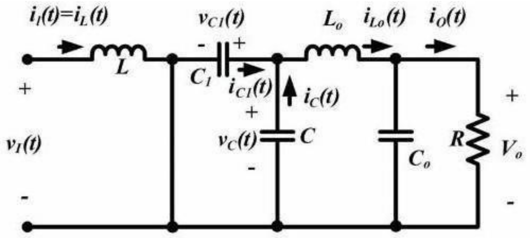

Fig6.CircuitdiagramofLuoConverterduring the Switch-ON time

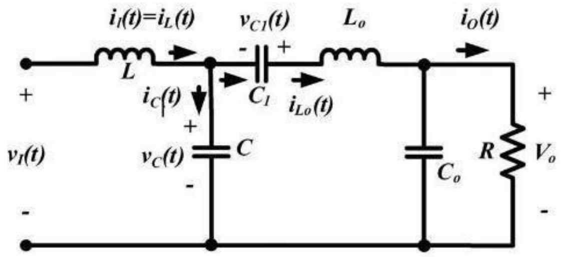

Fig7.Circuit DiagramofLuoConverter during the Switch-OFF time [14]

Luo converter is a unique DC-DC converter known for its superior features when compared to traditional competitors such as the Buck, Boost ,or Buck-Boost converter.

[14] It operates using a coupled-inductor architecture, which includes two inductors (L1andL2),twoswitches(SW1andSW2), and a diode (D). During operation, one switch conducts while the other is turned off, allowing constant energy transfer between input and output via the coupled inductors. Notably, the Luo converter maintains constant input and output currents during operation, resulting in smoother performance and less electromagnetic interference. [14] Its un usual topology also leads to lower input and output ripple currents, making it ideal for applications that require less noise. [8] With these features, the Luo converter achieves great efficiency and compact size, making it well-suited for diverse applications such as power supply, renewable energy systems, and electric vehicles.[14]

OPERATION OF ZETA-LUO CONVERTER

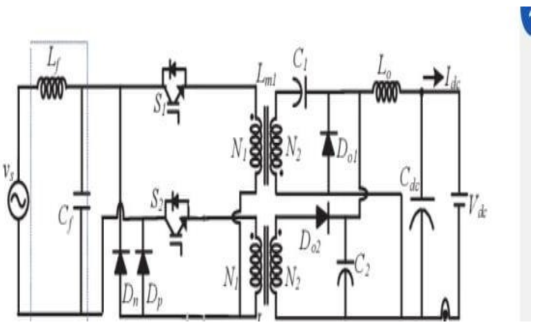

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Fig 8.Isolated Zeta-Luo Converter [15]

An [15] inventive way to effectively manage the power produced by photovoltaic (PV) arrays is the Zeta-Luo converter. It is directly integrated with the PV array and starts up with the Zeta converter stage, which modifies a switch's duty cycle to control the voltage of the array. [3] Step-up and step-down voltage conversions can be performed with this stage without the requirement for further energy storage parts. After that, the Luo converter stage uses a cascaded inductor-capacitor-inductor (L-C-L) network to further improve voltage regulation,

guaranteeing high efficiency and stable output voltage levels.[7] The outputs of these two converter stages are smoothly combined to produce an out put voltage that is reliable and efficient. Control circuitry continuously monitors and modifies the output voltage to ensure stability even under variable solar circumstances.

The Zeta-Luo converter contributes to the sustainable and effective use of solar energy by maximizing energy harvesting from the PV array while decreasing losses through optimizing energy conversion and use. The controlled output voltage provides a steady and dependable power source for a range of uses, including as charging batteries, directly powering electrical loads, or supplying excess energy to the grid.The integration of [15] Luo and Zeta converter concepts in the Zeta-Luo converter signifies a note worthy progression in renewable energy systems, augmenting their general dependability and efficiency.

Positive Half-Cycle (Zeta Converter Operation): - [15] The Zeta converter functions as a buck-boost converter during the positive half-cycle of the supplied voltage. Activating Switch S1 permits current to pass through the Zeta converter section.- ThemagnetizinginductanceLm1 charges the intermediate capacitor C1. - TheoutputdiodeDo1conducts,allowing Current to get to the load or battery.- In the meantime, switch S2 is still open and the Luo converter is still off, thereby isolating the Luo converter portion.[9]
Negative Half-Cycle[15] (Luo Converter Operation):-The Luo converter operates as a boost converter when the supply voltage is in its negative half-cycle. - The Luo converter section's current flow is enabled by the activation of Switch S2. - The intermediatecapacitorC2ischargedbythe magnetizing inductance Lm2. - When the output diode Do2 conducts, current can flowtotheloadorbattery.-SwitchS1stays open during this time, isolating the Zeta converter area, and the Zeta converter is not operating.

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Depending on the source voltage's polarity, the Zeta-Luo converter switches between Zeta and Luo converter functions. [15]It functions as a Zeta converter to provide buck-boost conversion during the positive half-cycle. On the other hand, it provides boost conversion when acting as a Luo converter during the negative half-cycle. The Zeta-Luo converter's hybrid operation enables effective energy transfer and voltage regulation, making it appropriate for a range of applications needing high efficiency and adaptable voltage conversion capabilities.

PHOTOVOLTAICSYSTEM

Photovoltaic cells are essential parts of solar energy systems; [5]they are usually composed of semiconductor materials such as silicon. Through the photovoltaic effect, these cells are able to directly convert sunlight into electricity by establishing an electric field through a particular treatment. PV cells, which range in size from a few square centimeters to several square inches, are thin semiconductor wafers that, when exposed to sunlight, generate electrical electricity.[5]

PV modules are made up of numerous PV cells linked to get her to increase the voltage and current outputs. These modules are made up of parallel and series connections between cells that are housed in tempered glass for protection and supported by frames.PV modules are the basic components of PV arrays and are available in a range of sizes and power ratings, from tens to hundreds of watts.

PV modules, often known as solar panels, are linked groups of solar cells with the purpose of effectively absorbing sunlight and transforming it into electrical power. They are essential components of photovoltaic systems, which are used in commercial, industrial, and residential settings. These panels meet arrange of energy needs with their different sizes and power ratings.[5]

PV arrays are larger solar energy producing devices made up of connected PV modules. These solar farms, which can be as tiny as rooftop installations or as large as massive arrays, use sunshine to generate electricity. PV arrays allow effective conversion and consumption of energy and are often complemented by wiring, inverters, mounting frames, and other components.

Essentially, the PV system is made up of PV cells ,modules, and arrays, all of which play essential roles in capturing solar energy and enabling its conversion into electrical power that can be

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used.[10]

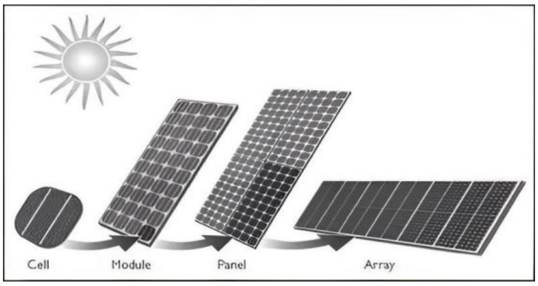

Fig9.PhotovoltaicSystem

DESIGNANDSIMULATION

The Zeta-Luo converter simulation diagram, which uses a photovoltaic (PV) array, has several key parts and phases. First, by transforming[7] sunlight into electrical energy, the PV Array—which is made up of solar panels—acts as the main supply of DC power. The Zeta-Luo converter uses MOSFETs, or metal-oxide- semiconductor field-effect transistors, as switches to control the current flow through the converter stages. By continuously adjusting the PV array's operating point to the maximum power point (MPP) under changing environmental conditions, the Maximum Power Point Tracking (MPTT) control algorithm optimizes the power output of the array.

Through the production of signals that regulate MOSFET switching, the Pulse- Width Modulation (PWM) Generator ensures effective energy ransfer and output voltage regulation. The PV array's DC voltage output is converted by the Universal Bridge circuitry into AC voltage that is appropriate for grid connection.It may also include parts for power conditioning and synchronization, such as invertersorconverters.TheZeta-Luoconvertersystemandtheelectricalgridcan communicate more easily thanks to the Grid Connection interface, which also makes it possible to filled ficiencies and feed surplus energy from the PV array back into the grid.

The Zeta-Luo Converter stage, which combines the principle so the Zeta and Luo converters for efficient voltage conversion and control, effectively regulates the voltage from the PV array. The Battery,

which represents the energy storage component in off-grid or hybrid systems during times of low sunlight or peak demand, stores excess PV energy for later use.[9] Overall, the simulation diagram shows how effective solar energy harvest in gand power flow management are made possible in both grid-connected and freestanding applications through the integration of the PV array, battery, and control components

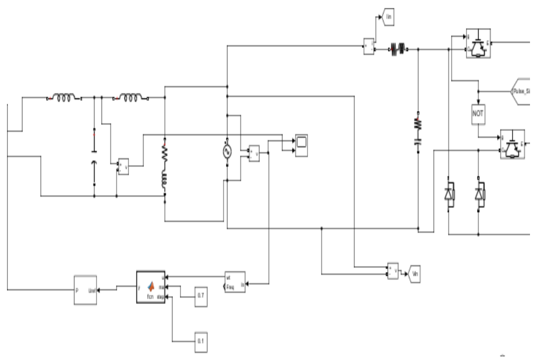

Fig10.Isolatedzetaconverter

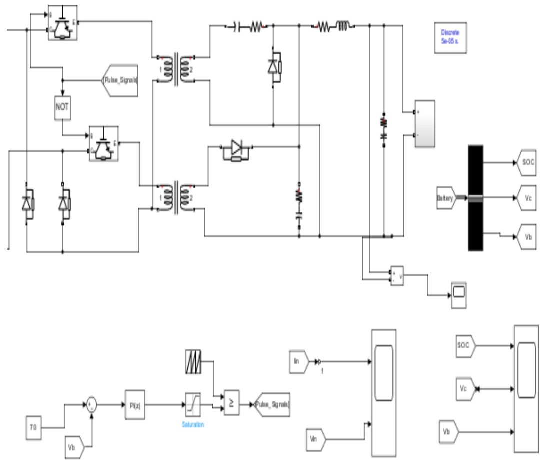

Fig11. Isolated Luo converter

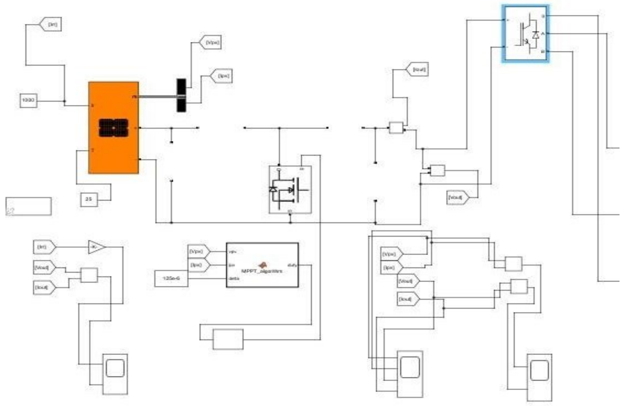

Fig12. PVArray

OUTPUTWAVEFORMS

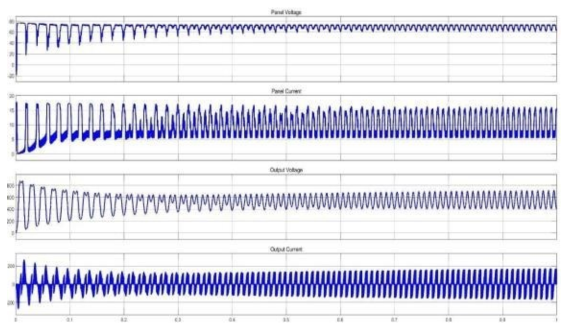

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Fig13.SolarPanelOutputWaveform

The waveform designated as "panel voltage" demonstrates features of a sinusoidal wave. The phase shift, amplitude, frequency, and period are some of these properties.

The horizontal distance between two identical locations on the wave is represented by the period, which is represented as 200 in the illustration. This distance indicates how long it takes for a whole cycle to recur. The reciprocal of the period, or 0.005 Hz in this instance, can be used to compute the wave's frequency.

The vertical distance between the wave's crest (or trough) and the center line is indicated by the wave's amplitude ,which is shown in the picture as 200.

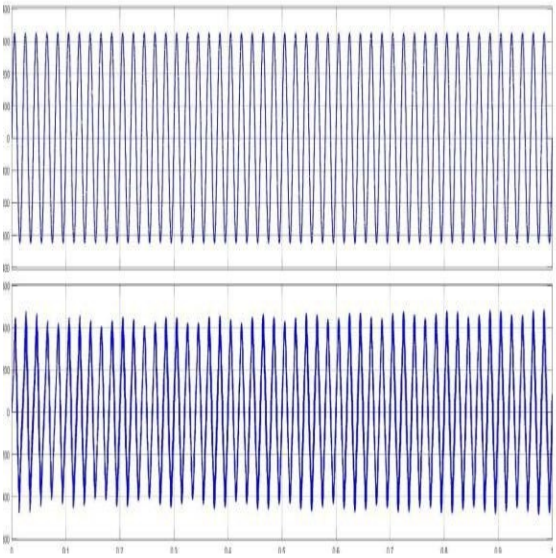

Fig14.Gridinput Waveforms

Both waveforms are sinusoidal. Wave-like patterns that smoothly repeat are known as sine waves. The amplitude of the top wave form (INPUTVoltage) is greater than that of the bottom waveform. The distance between the wave's crest or trough and the center line, a horizontal line that runs through the middle of the wave, is referred to as the wave's amplitude.The top waveform in the illustration has smaller dips and higher peaks than the bottom waveform.

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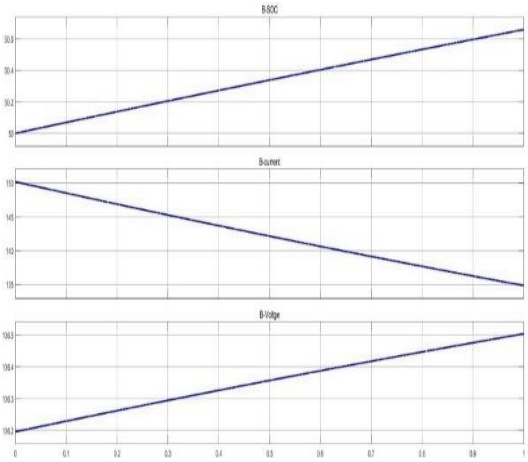

Fig15.Simulationgrapofbatteryparameters

Three sinusoidal waveforms are shown in the picture; they are identified as"B-SOC,""B-Voltage," and "B-Current." The sine wave's smooth, repeating patterns can be seen in these waveforms. In comparison to the other two waveforms, the "B-SOC" waveform exhibits the highest amplitude, with larger peaks and lower dips. On the other hand, the amplitude of the "B- Voltage "wave for mis the smallest,and the amplitude of the "B-Current" waveform is in between the other two. The frequency of all three waveforms appears consistent despite differences in amplitude because they show the same number of cycles per unit distance along the horizontal axis. In conclusion, three sinusoidal waveforms with varying amplitudes and constant frequencies are depicted in the illustration.

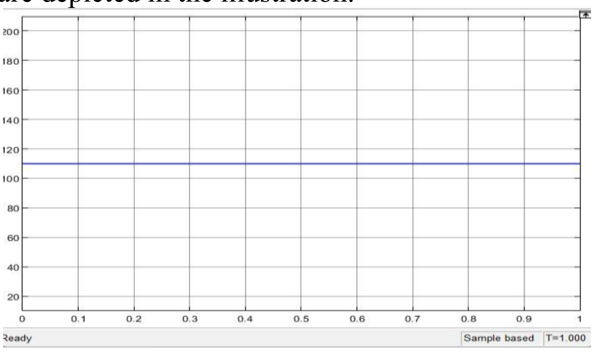

Fig16.Output waveform

The imaged scribes analyzing a wave form it is likely as in wave.It has Key properties like amplitude (height from center), wavelength (distance between cycles), and frequency (cycles per unit time)

CONCLUSION

Combining a Zeta-Luo converter with a photovoltaic (PV) array to charge electric vehicles (EVs) is an exciting new direction for sustainable transportation and renewable energy. Through this study, we have shown the feasibility and efficiency of implementing this innovative converter design into EV charging infrastructure. The Zeta-Luo converter integrates the best features of the Zeta and Luo converters to deliver efficient voltage control and energy conversion from the PV array. By harnessing solar energy, it offers a sustainable and ecologically friendly way to power electric vehicles.

Our findings suggest that the Zeta-Luo converter is capable of optimally controlling the PV array voltage, ensuring reliable and consistent EV charging, and maximising the efficiency of solar energy harvesting.

In addition, by incorporating the Zeta-Luo converter into EV charging infrastructure, new opportunities for enhancing transportation efficiency and sustainability may be realised. Using renewable energy sources, such as solar power, may lessen transportation's negative impact on the environment and reduce our reliance on fossil fuels.

Ultimately, the use of a solar array in the EVcharging project by Zeta-Luo has the ability to hasten the transition to renewable energy-powered mobility.Together, through persistent research and innovation, we can realise the vision of a transportation system that is cleaner, more efficient, and less harmful to the environment.

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11) DesignandImplementationofIsolated Zeta-Luo Converter for EV ChargingApplications

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12) Review on Unidirectional Non-Isolated HighGainDC–DC Converters for EV SustainableDCFastChargingApplications

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13) DesigningDC/DCconvertersbasedon ZETA topology By Jeff Falin Senior Application Engineer

14) Luo Converter For Low-Power Applications Using A Super Capacitor

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15) BridgelessIsolatedZeta-LuoConverter Based EV Charger with PF Pre-regulation

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16) PerformanceAnalysisofZetaConverter in Wind Power Application

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