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Research Paper

Electric Vehicles with Dual Batteries Made Easier with New Reconfigurable Power Converters.

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Abstract — There has been a meteoric rise in the demand for electric vehicles (EVs) powered by batteries recently. Anxieties about EV range and reliability are the main roadblocks to the industry's expansion. A new trend in electric vehicles, especially in the two-wheeler market, is the use of dual batteries to tackle these issues. Two new programmable power converters that can integrate two batteries are shown in this research. When charging or traction, the converters let you use only one battery, or they may link the two batteries in parallel or parallel. You may connect the converters' outputs straight to the charger and traction inverter. The terminal potentials of the two batteries must be very close to one another for the parallel connection to work with minimal circulating currents. To do this, the converters that are being considered have a voltage balancing function. A non-isolated inverters charger system (ICS) incorporates the suggested converter to exhibit dual battery charging. State space averaging while small signal modeling were used to construct transfer functions in the system using the proposed converter, and the K-factor technique was used to build the requisite controllers. The efficacy of the suggested power converters is validated by the presentation of thorough MATLAB calculations and hardware trials.

Electric cars, propulsion, series-parallel battery configuration, bidirectional power flow, reconfigurable power converters, inverter charger systems, dual battery systems, and so on.

INTRODUCTION

The increasing pollution and its detrimental effects on the environment are bringing cleaner sources to the attention of more and more people. With 29% in the US and 20% globally, the transportation sector was responsible for more than a third of carbon dioxide emissions in 2022 [1]. There has been a dramatic shift in the transportation sector toward electric vehicles and away from internal combustion engines. The sales of electric vehicles (EVs) in Norway expanded substantially during the last decade, rising from 3% in 2010 to over 86% in 2022 [2]. Less noise pollution, better economy, lower running costs, less maintenance, & zero carbon footprints are other advantages of battery-powered cars [2]. Despite the many advantages, widespread use of electric vehicles is not without its many negative aspects. Problems with dependability, longer charge times, higher purchasing costs, and range anxiety are all on the list. Improved battery technology, shorter charging periods, and the ability to swap out batteries are all possible solutions to the issue of short battery life. It will be quite some time before the benefits of the gradual but constant improvements in technology for batteries and quick charging capacity become apparent. Even though battery switching has potential, bigger vehicles like trucks and cars will have a hard time implementing it due to the enormous size of an onboard battery. Additional obstacles include issues with battery possession, a lack of charging facilities, and the absence of worldwide standards for battery replacement

[3]. The electric vehicle industry is considering using dual energy storage systems to circumvent the aforementioned problems. The researchers primarily used batteries as their primary instrument for energy storage, with an ultracapacitor (UC) serving as their secondary tool. In order to handle surge or peak power demands, they used the UC's high density of power. It increased the overall range of electric cars and made the main battery last longer. Due to their low energy density, UCs cannot replace the primary battery in case the latter fails or completely discharges. According to authors in [15], [16], [17], and [18], the idea of having two batteries with different chemistry has been discussed. These configurations, which employ two batteries, substantially expand the driving range of EVs on a single recharge. According to the authors in citation [16], it is possible to adequately satisfy the power & energy demands of EVs via two battery sources. According to [20], a dual inverter & two batteries are used in tandem to power the open-end winding motor.

RELATED WORK :

"City planning, alternative energy, bicycles, and rail should be added to electric vehicles in order to decarbonize road transport,"

Almost the whole cost of ownership, including buying and operating one, has dropped below the level of a conventional gas-powered vehicle. Vehicle charging systems have grown in many nations, and engineers and scientists have increased the amount of energy that can be stored in EV batteries, allowing for longer cruising distances. One example is the United States, which is home to over 49,000 public charging stations. Thanks to these networks, it is now feasible to drive an electric vehicle from New York to California.

"A survey of the methods, regulations, developments, and future of ev technology in Germany,"

Direct current (DC) microgrids are becoming increasingly important due to a number of Electric Vehicle development has been adopted as one of the national policies by the German Government as the country desires to reduce carbon emissions and address energy problem. Germany has invested a lot in the EV development. Since the launch of National Platform Electromobility in 2010 there has been continuous development in EV industry of Germany. In this paper, first the EV charging technologies are discussed, which is then followed by the elaboration of the EV charging standards by the major standardization organizations. The study then mentions the status quo and projected

development of EV technology in Germany focusing on the development of charging infrastructure and battery technology. This is followed by highlighting the efforts made by German auto manufactures in the field of Electromobility and comparison with their American and Chinese counterparts. The paper then identifies the hurdles that are present in the path of achieving the goal of 1 million EVs by 2020. Then, overview of the EV developing strategy in Germany to address the challenges is presented which is followed by conclusions and references.

An innovative and practical way to create a sustainable energy environment that incorporates sources of renewable energy (RES) with storage systems for energy (ESS) electricity the direct current microgrid. In this piece, we take a look at a new PDCS that was developed for microgrids that use small-scale wind energy to generate low-voltage direct current (LVDC). Because wind energy is intermittent and stochastically volatile, and because load demand might vary unexpectedly, microgrids that use wind power must also have storage devices with high power densities. For this purpose, the 48 V LVDC bus is connected to a hybrid system for energy storage (HESS) that uses batteries and supercapacitors (SCs). In order to increase the battery's cycle life, hybridization primarily aims to reduce the need for immediate surge current and to lessen the strain on the battery from rapid charge and discharge. This improves the dependability and efficiency of the integrated wind system. Faster control of the 48 V DC bus voltage and improved power-sharing between the battery and SC are two benefits of the suggested PDCS that help to close the gap between demand and generation. The proposed system also keeps the state-of-charge (SOC) within the operational limitations. Experiments with several case studies test the constructed autonomous LVDC system using the proposed PDCS. Evaluation of the PDCS's effectiveness and its ability to switch between modes with ease is supported by comparative testing results. Also, the new method speeds up SOC recovery by controlling the charge and discharge of SC..

"A three-wheeled electric vehicle's energy- and power-split control of its twin energy storage systems,"

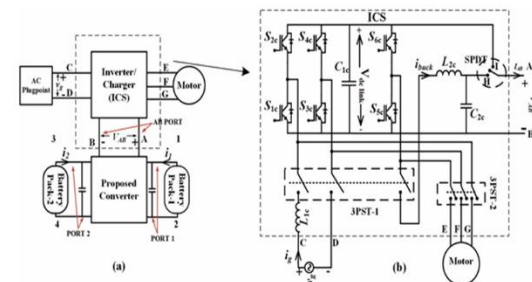
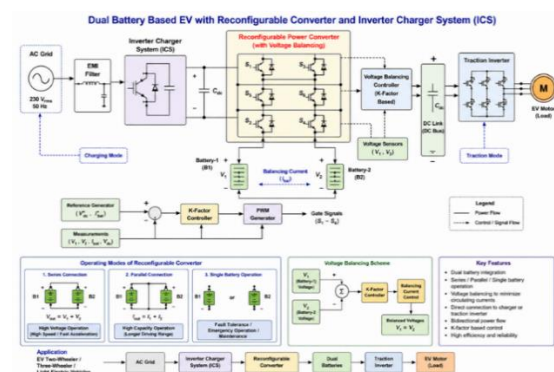
Recreational vehicles are one example of an application that calls for innovative system for storing energy (ESS) technology. There have been some encouraging developments in battery technology recently, but the current power-to-energy ratio is still inadequate for these types of vehicles. In this article, we take a look at how a three-wheel electric automobile may include a SuperCapacitors (SCs) pack, with an eye on managing the energy and power split. In order to

improve the vehicle's overall efficiency and performance, an energy-management strategy is implemented that relies on a complete fuzzy logic controller technique. A clever handling of the SCs' energy levels is part of the suggested control and management method, which also makes sure that the battery provides the average percentage of the power requirement. You may simply modify the technique to work with various cars or other ways of driving. For a smaller-scale hybrid dual ESS, the method was tested on a power-level hardware-integrated loop (HIL) platform. This experimental test assesses the capacity to better coordinate the flow of energy and enables for real-time verification for the proposed energy management. When compared to an architecture that relies only on batteries, the suggested method extends the life of the batteries by 12% by lowering the root-mean-square (RMS) value of the battery current.

Managing the power and energy of an electric car with two power sources – challenges in putting policies into practice,

This study presents a novel design-oriented strategy for managing the power and energy consumption of electric vehicles (EVs) that run on a dual-sourced system, and it deals with the implementation challenges that come with such a policy. As a method for changing states, a unique sequential decision-making technique has been developed to ascertain the reference energy levels and power split ratio of the two battery-ultracapacitor sources. Preliminary data from a test car was used to verify the accuracy of the tractive power demand and battery behavior simulation models.

Methodology:



The first figure shows a block design of the proposed converter linked to an ICS (Integrated Charger Power Converter System), while the second graphic shows the ICS's circuitry. The ICS may be connected to either the grid or a traction motor.

1.CONVERTERS :

A power electronic system cannot function without power electronic converters. In order to control a variety of power semiconductor devices, a power electronic converter uses integrated circuits. Switching power semiconductor devices allows power electronic converters to change the form of input power.

1.1.1 TYPES OF CONVERTERS:

- AC-AC converter
- AC-DC converter
- DC-DC converter
- DC-AC converter

AC-AC CONVERTER:

By adjusting the voltage and frequency, an AC-AC converter may transform one alternating current (AC) waveform—like the one from the wall outlet—into another AC waveform. The term "cycloconverter" might also describe it. The cycloconverter is usually fed one or three phases of alternating current (AC) from the mains. Frequency and voltage are both constant. It is the cycloconverter that provides the output, which varies with both voltage and frequency. The frequency of the output is lower than that of the input. Cycloconverters are the most common component of AC traction drives.

AC-DC CONVERTER:

A "rectifier" is a voltage converter that takes an alternating current (AC) and converts it to direct current (DC). Rectifiers are pieces of

electrical apparatus that change the flow of electricity from current alternating (AC), which is characterized by alternating polarity, to alternating current (DC), which is characterized by straight lines.

DC-AC CONVERTER:

When converting from DC to AC, a device is known as an inverter. You may modify the voltage and frequency of alternating current (AC) from direct current (DC) using the correct transformers, switches, and regulate circuits in an inverter. It is the inverter's function to reverse the process of a rectifier.

DC-DC CONVERTER:

Using a converter that converts is one method of converting DC current back into DC form. There is usually a voltage difference between the input and output. The regulation of power buses and the prevention of background noise are two further areas where DC-to-DC converters find utility. Deactivating and activating switches like diodes, transistors, MOSFETs, and so on performs the conversion operation. Switch mode conversion describes this process as it occurs. Using a conventional DC-to-DC converter limits the input-to-output power flow to a single direction.

2. HALF-WAVE RECTIFIER:

The half-rectification of an alternating current wave allows just one half of an alternating wave to pass through. Since the output is just half the size of the input waveform, the power transfer rate is pitiful. While half-wave rectification may be achieved with only one diode in a single-phase supply, a total of three are needed in a three-phase supply.

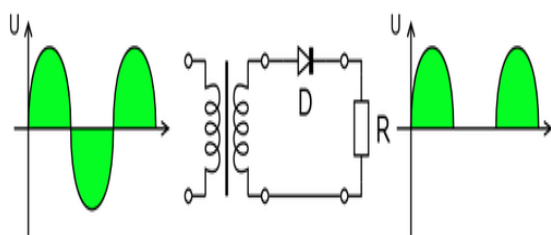


Fig 2. Half-Wave Rectifier

A half wave rectifier's output direct current voltage may be determined using these two ideal equations:

$$V_{rms} = V_{peak}/2$$

$$V_{dc} = V_{peak}/\pi$$

2.1 FULL-WAVE RECTIFIER:

A full-wave rectifier changes the whole input waveform into an output waveform of specified polarity (positive or negative). The best way is full-wave correction, which converts the polarity of the input waveform to direct current (DC). Four diodes are required for half-wave rectification in a circuit that employs a non-center tapping transformer, as opposed to one. One kind of rectifier circuit that utilizes four different diodes in this arrangement is called a diode bridge.

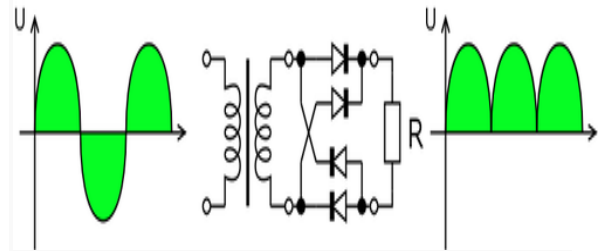


Fig 2.2 Full-Wave Rectifier (1)

For single-phase AC, a center-tapped converter using two full-wave rectifier configurations of diodes (anodes-to-anodes or cathodes-to-cathodes) may be used. It takes twice as many secondary windings of the transformer to provide the same voltage result than the bridge rectifier.

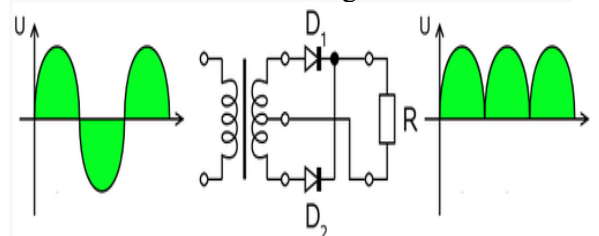


Fig 2.2 Full-Wave Rectifier (2)

In order to make the most economical use of a single tube for both diodes, it was common practice for vacuum tubes rectifiers to have a single cathode with two anodes contained in a single housing. The 5U4 & 5Y3 were two famous cars that used this configuration. The vast majority of alternators, which are essentially alternating current generators, output three-phase AC. For example, a car alternator uses a full-wave rectifier consisting of six diodes to charge the batteries.

The average or root-mean-squared output voltages of a faultless single-phase full-wave rectifier are as follows:

$$V_{dc} = V_{av} = 2V_p/\pi$$

$$V_{rms} = V_p/\sqrt{2}$$

Where:

V_{dc} , V_{av} - the average or DC output voltage,

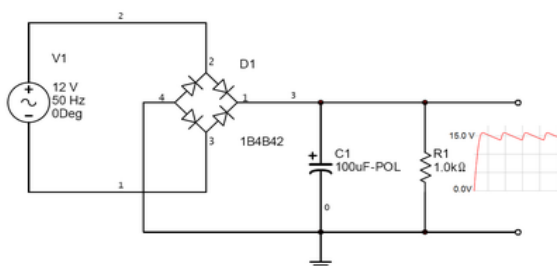
V_p - the peak value of half wave,

V_{rms} - the root-mean-square value of output voltage.

$$\pi \approx 3.14159$$

2.2 RECTIFIER OUTPUT SMOOTHING:

Both half-wave and full-wave rectification can provide DC output, but neither of these approaches guarantees a consistent voltage for the DC. Consistent direct current (DC) from rectified alternating current (AC) requires a filter and smoothing circuit. One easy way to do this is to connect a reservoir a smoothing capacitor to the rectifier's DC output. A little amount of AC voltage ripple will persist despite all attempts to smooth it down.



Using the Multisim 8 program, the RC-filter rectifier circuit was constructed and simulated (Fig. 2.2).

3. RECTIFICATION TECHNOLOGY

3.1 MECHANICAL ELECTRIC

In the beginning, power conversion systems depended only on electromechanical design since electronic devices couldn't handle significant power. The input power origin's frequency is often maintained via mechanical rectification devices, which rely on rotation or

resonating vibration and can only operate at rates of a couple of thousand cycles per second.

The intrinsic complexity of mechanical systems has always meant that they have needed substantial upkeep to function properly. Lubricating moving parts reduces friction, which in turn prevents wear and, eventually, replacement. Mechanical connections may be damaged or even burned by electrical arcs and sparks when opened while under load.

4. BOOST CONVERTER

The DC voltage input is increased using a boost conversion, also called a step-up converter, which results in a higher DC voltage output. At least three silicon switches, including a diode and a transistor, are used in this kind of SMPS, which employs energy storage. A capacitor filter, often combined with an inductor, is commonly fastened to the converter's input in order to reduce voltage ripple.

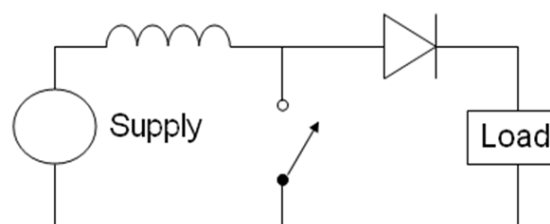


Fig 4.1 Boost converter

Some common DC power sources are batteries, solar energy systems, rectifiers, and DC generators. A process that changes one direct current voltage into another direct current voltage is known as a DC-to-DC conversion. Boost converters are a kind of DC-to-DC converter that increase the output voltage above the input voltage. A step-up converter is one kind of power converter; this type of converter raises voltage derived from the source, thus the name. Because of power saving ($P = VI$ and $P = a$ creative UI in Europe), the voltage drop between the input and output terminals is less.

An increase converter circuit is schematically shown in Fig.

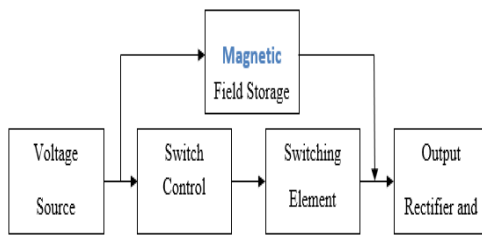


Fig 4.2 Block diagram

The source unit load would be left idle in a frequency-sensitive application because a substantial voltage difference is needed to current to flow across a load.

4.3 OPERATING PRINCIPLE:

The basic principle of an inductor's resilience to current variations is the basis of the boost converter's operation. Similar to how a battery interacts with a load, it acts as a resistor when charged or a source of energy when depleted. Discharge allows for a wide range of input as well as output voltages as the voltage it produces is directly proportional to the rate of current change rather than the voltage applied at the beginning of the charge cycle.

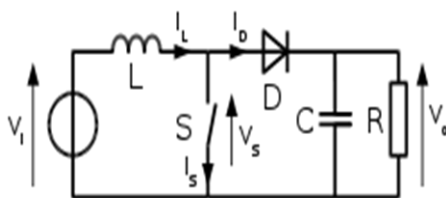
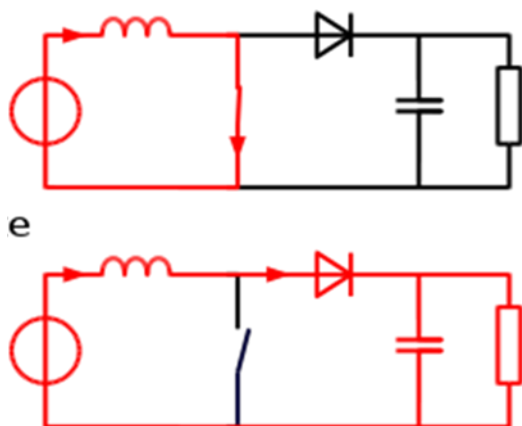


Fig: 4.3 Boost converter schematic



Two possible boost converter setups are shown in Fig. 4.4, one for each possible state of the change s.

See Figure 4.4 for an illustration of the two separate states that make up the fundamental concept of a Boost converter:

5.CONTINUOUS MODE:

Zero current via the inductor (I_L) is impossible to achieve while operating a boost converter in continuous mode. The standard current and voltage waveforms in the illustration demonstrate this mode of operation. With a flawless converter (i.e., components that behave perfectly) running constantly, this method may be used to calculate the output voltage:

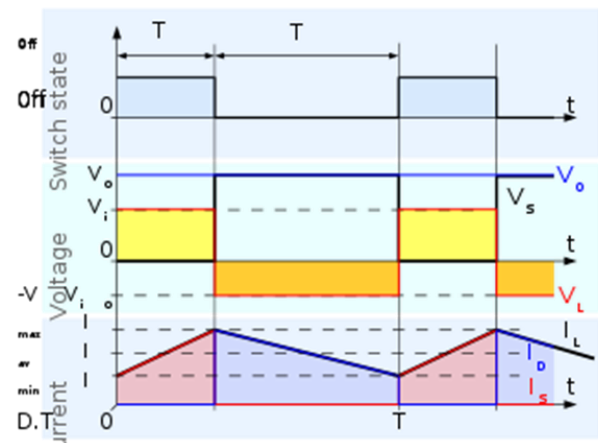


Figure 4.5 shows the current and voltage waveforms produced by a continuous-mode boost converter.

The voltage at the input (V_i) is applied across the inductor while the On state is in effect because the switch S is closed, and this change is determined by the formula calculating the change in current (I_L) flowing across the inductance throughout a time period (t):

$$\Delta I_L / \Delta t = V_i / L$$

Therefore, the rise in I_L is:

$$\Delta I_{L\text{On}} = 1/L \int_0^D V_i dt = D V_i / L$$

D stands for duty cycle. This number represents the fraction of the commuting period T that the toggle is actively processing data. Consequently, D may take on values between 0 (S remains off) and 1.

When switch S is activated, which represents

the Off-state, current flows through the load from the inductor. If the diode doesn't lose voltage and the capacitor is large enough to keep the voltage constant, then I_L may continue to grow.

$$V_i - V_0 = L di_L/dt$$

Consequently, the differences in I_L when there is an off-period are:

$$\Delta I_{LOff} = 0 \int (1-D)T (V_i - V_0)dt/L = (V_i - V_0)(1-D)T/L$$

Since the converter operates in a steady-state environment, the amount of energy stored in each component must remain constant at the start and end of a commutation cycle. Here is the precise way the voltage of the in stored energy is presented:

$$E = 1/2 L I_L^2$$

Therefore, the inductor current must remain constant from the start of the commute cycle until its finish. So, overall, the current has not changed (i.e., the sum of the modifications has not changed):

$$\Delta I_{LOn} + \Delta I_{LOff} = 0$$

Substituting ΔI_{LOn} and ΔI_{LOff} by their expressions yields:

$$\Delta I_{LOn} + \Delta I_{LOff} = V_i DT/L + (V_i - V_0)(1-D)T/L = 0$$

Another way to express it is:

$$V_0/V_i = 1/(1-D)$$

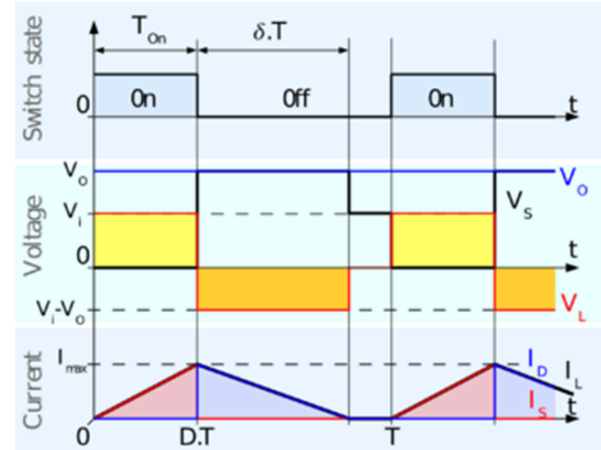
Consequently, what does the duty cycle show as?

$$D = 1 - V_i/V_0$$

According to the preceding formula, the final voltage is always larger than an input voltage (as duty of cycle increases from 0 to 1) while it climbs with D , potentially reaching infinite as D approaches 1. A step-up converter is another name for this kind of converter due to the fact that.

5.1 DISCONTINUOUS MODE:

Transferring energy does not always need the commutation time if the load's energy demands are low. The current through the inductor is zero for a certain amount of time. To see the only exception from the aforementioned concept, refer to the figure's waveforms: the inductor is completely drained after the commutation cycle ends. The output voltage equation is drastically changed by the little difference. I have included the calculating algorithm below.



The current and voltage waveforms of a boost converter running in discontinuous mode are shown in Figure 4.6.

At time zero (DT), the inductor current is zero, so its highest level value I_{LMax} is:

$$I_{LMax} = V_i DT/L$$

In the off-period, after δT , I_L is zero.

$$I_{LMax} + (V_i - V_0)\delta T/L = 0$$

By using the two preceding equations, we can determine that δ is:

$$\Delta = V_i D/(V_0 - V_i)$$

Load current, or I_o for short, is the average current across a diode. The current through the diode and inductor are identical in the off state, as seen in figure 4. And therefore, what is happening at the result may be written as:

$$I_o = I_D = I_{LMax} \delta / 2$$

When the formulas for I_{Lmax} and δ are substituted, the result is:

$$I_o = V_i DT/2L \cdot V_i D/(V_0 - V_i) = V_i^2 D^2 T/2L(V_0 - V_i)$$

As a result, we can express the voltage that comes out gain as flow:

$$V_0/V_i = 1 + V_i^2 D^2 T/2L I_o$$

This is a somewhat more complex equation compared to the one for the output voltage of the continuous mode. Discontinuous operation's output voltage gain is sensitive to a number of parameters, including as input voltage, duty cycle, inductor value, switch frequency, or output current.

6. BUCK CONVERTER

5.1 INTRODUCTION:

An additional term for a DC-to-DC converter that uses a step-down process is a buck converter, or buck converter. Using an inductor, capacitor, plus two different switches (a transistor and a diode), it is a switched-mode power supply similar to the step-up boosted converter.

Though they are simple and fast, voltage splitting circuits are inefficient because they generate heat while operating and their final power isn't constant; it varies with the input voltage. For example, buck converters are ideal for converting a laptop's 12-24 V charge to the few of volts needed by the CPU because of their self-regulating nature and great efficiency.

Theory of operation

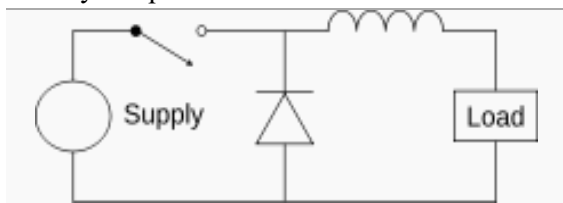
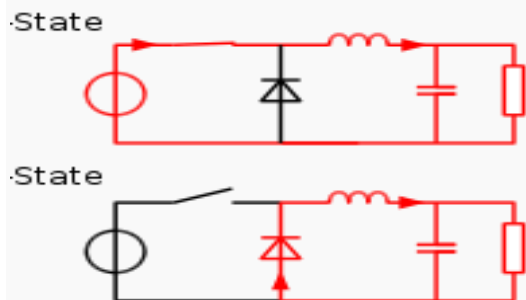


Fig: 5.1 Circuit schematic for a buck converter.



If the toggle is closed, the buck converter is in its "On" state; otherwise, it is in its "Off" state, as shown in Figure 5.2.

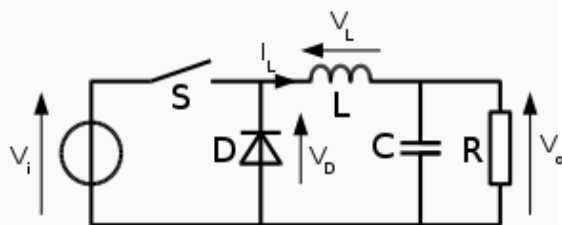


Fig:5.3 Standardization in naming the buck converter's components, voltages, and currents.

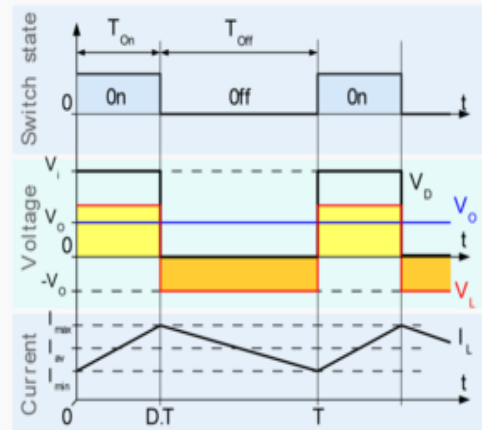


Fig:5.4 Time-dependent voltage and current evolution in a perfect continuous-mode buck converter.

The buck converter may function well with only an inductive device and two switches, often a type of transistor and a diode. It will link the inductor to the the source voltage and discharge it into the load at regular intervals so that it may store energy.

5.2 CONTINUOUS MODE:

When operating in continuous mode, the buck converter ensures that each commutation cycle is uninterrupted by keeping an inductor current (I_L) from dropping below zero. This is how the functioning mechanism is explained by the chronogram in the illustration.

When the switch is in its closed mode (On-state, above figure 2), the voltage across an inductor becomes $V_L = V_i - V_o$. An inductor's current-increasing capabilities are linear. No current will pass through the diode since it is being supplied with an inverse bias by the voltage source V . When the switch is turned off, as illustrated at the bottom in figure 2, the diode turns forward. Considering the voltage that exists across an inductor without the diode loss is $V_L = -V_o$. Reducing I_L in the present.

The energy stored in inductor L is

$$E = \frac{1}{2} L I_L^2$$

During On-time, L 's energy storage increases (in reaction to growing I_L), but during Off-state, it decreases. Transferring energy from its source to its destination is L 's primary purpose. One way to determine the I_L rate of change is by using:

$$V_L = L \cdot \frac{dI_L}{dt}$$

During the On-state, V_L is equal to $V_i - V_o$, while during the Off-state, it is equal to $-V_o$. The result is the following expression for the current growth during the On-state:

$$\Delta I_{L\text{on}} = \int_0^{t_{\text{on}}} V_L/L \, dt = (V_i - V_o)/L \, t_{\text{on}}$$

Similarly, during the Off-state, the reduction in current is given by:

$$\Delta I_{L\text{off}} = \int_0^{t_{\text{off}}} V_L/L \, dt = -V_o/L \, t_{\text{off}}$$

The energy stored in each component remains constant at its starting value while the converter operates in steady state, for a certain commutation cycle T . Thus, the current I_L is identical at time as well zero as well as time T (according to figure 4). Hence, since

Based on the equations given above, we may express:

$$(V_i - V_o)/L \, t_{\text{on}} - V_o/L \, t_{\text{off}} = 0$$

The aforementioned integrations may, of course, also be done visually: Thus, $\Delta I_{L\text{on}}$ and $\Delta I_{L\text{off}}$ are precisely proportional to the areas created by the yellow and orange areas in figure 4, which are defined by the voltage of the inductor (red) curve. Since both of the surfaces are basic rectangles, the area of the yellow rectangle is $(V_i - V_o)t_{\text{on}}$ and the area of the orange rectangle is $-V_o t_{\text{off}}$. A steady state operation of the system requires that these areas be equal.

$$\text{This yields } (V_i - V_o)DT - V_o(1-D)T = 0$$

$$V_o - DV_i = 0$$

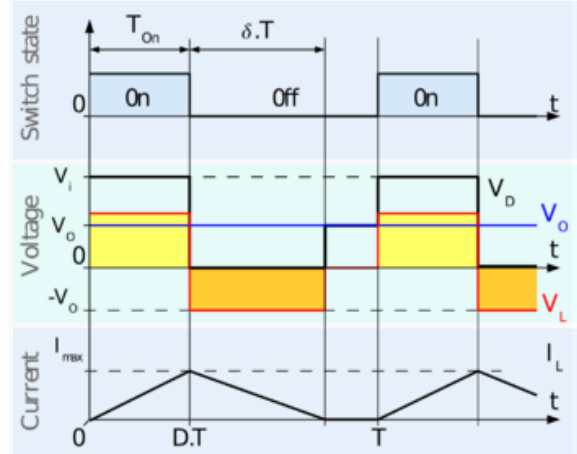
$$D = V_o/V_i$$

A linear relationship between duty cycle and the voltage that comes out of the converter is shown for all input voltages by this equation. Due to its proportionality to the ratio of upon-time to total period T , the duty cycle D can only take on values larger than 1. The term "step-down converter" is thus based on this particular phenomenon.

5.3 DISCONTINUOUS MODE:

When the energy demands of the load are minimal, the time required for transfer is less than the total time required for commutation. For some time during this scenario, the current flowing through the inductor will be zero. The one and only change from the given notion is that the inductor is completely discharged after the commutation cycle ends. Yet, this does alter the solutions to the previous equations

somewhat.



The ideal buck converter in discontinuous mode shows the voltage and current evolution with time in Fig:5.5.

Let us pretend for the moment that a converter is running at a constant current. Therefore, the energy of the inductor is 0 in discontinuous modes and constant over the cycle. The average inductor voltage (V_L) is 0 because the region between the image's yellow and orange squares is equal.

The result:

$$(V_i - V_o)DT - V_o\delta T = 0$$

So the value of δ is:

$$\delta = (V_i - V_o)/V_o D$$

The constant output current (I_o) supplied to the load is a result of the output capacitor's ability to maintain a constant terminal voltage over a commutation cycle.

RESULTS :

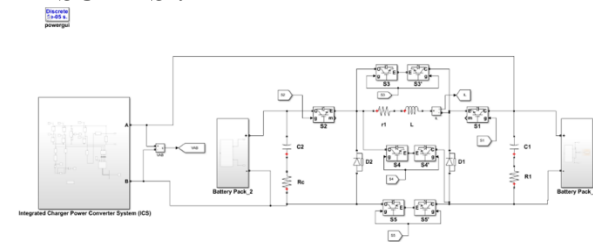


Fig.1. MATLAB/SIMULINK circuit of the system

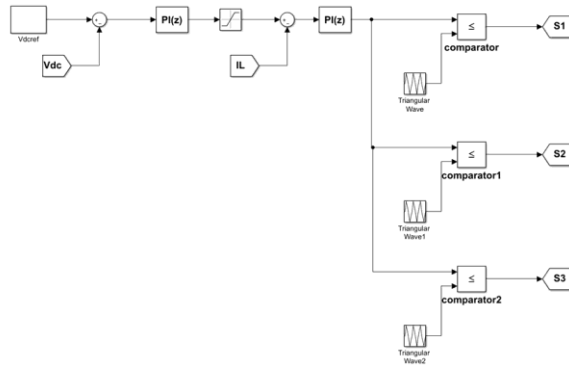
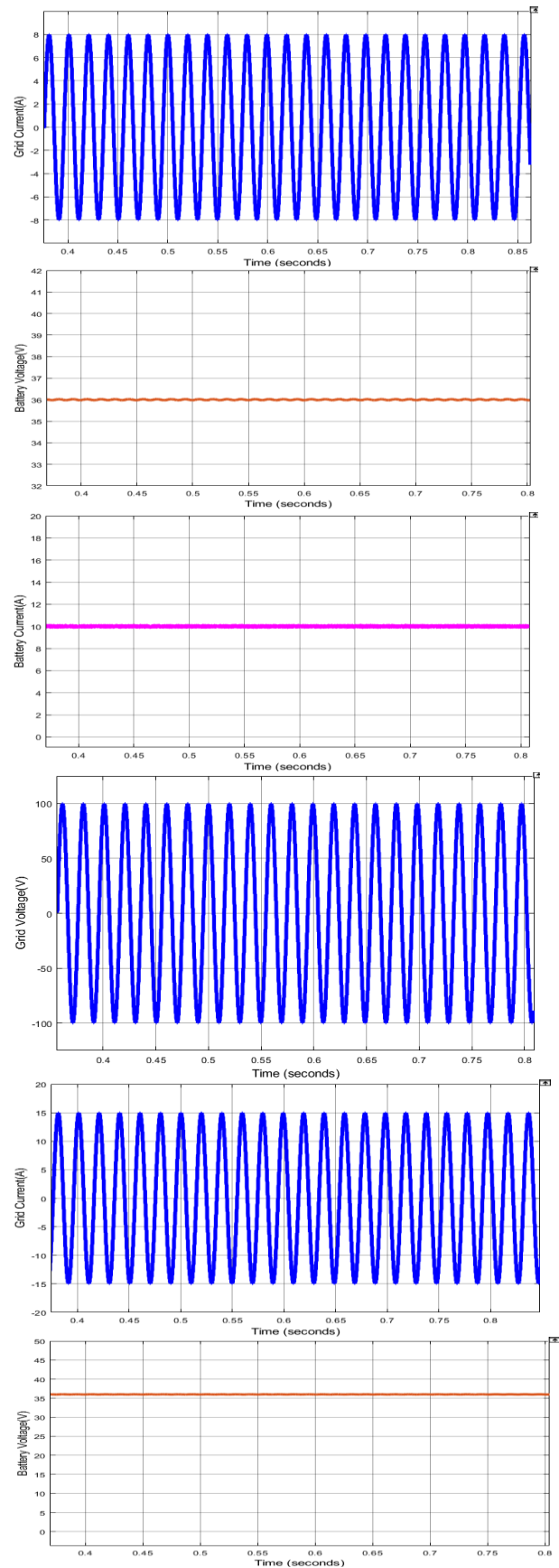
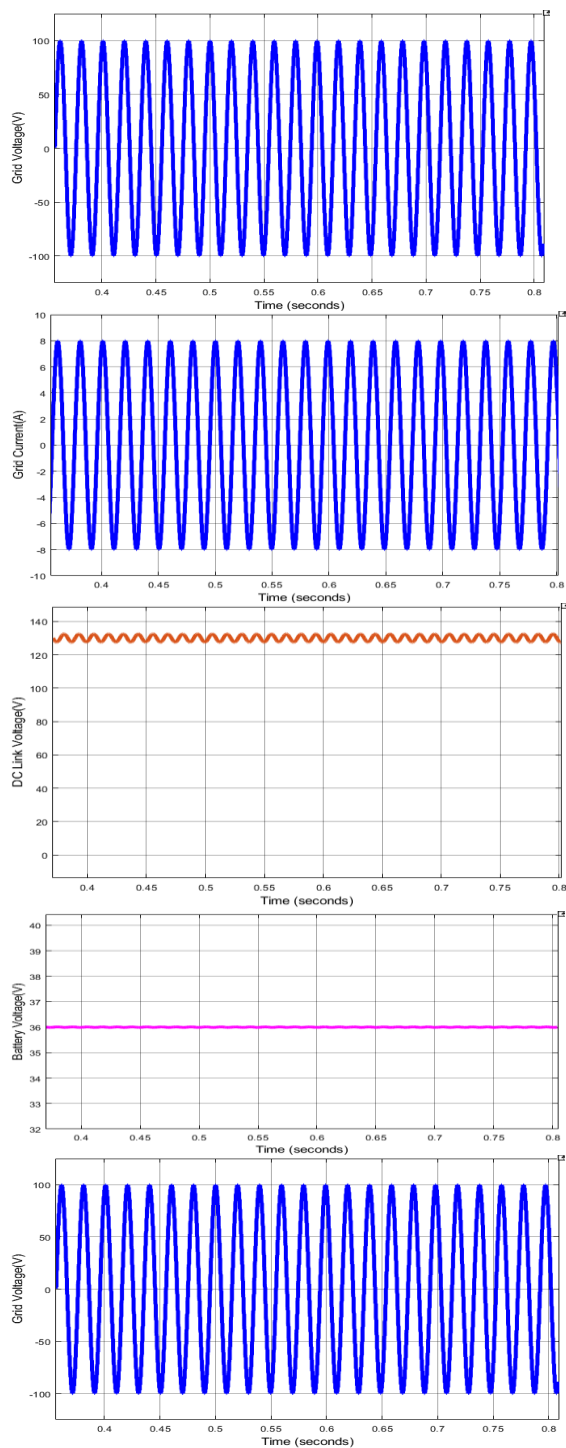
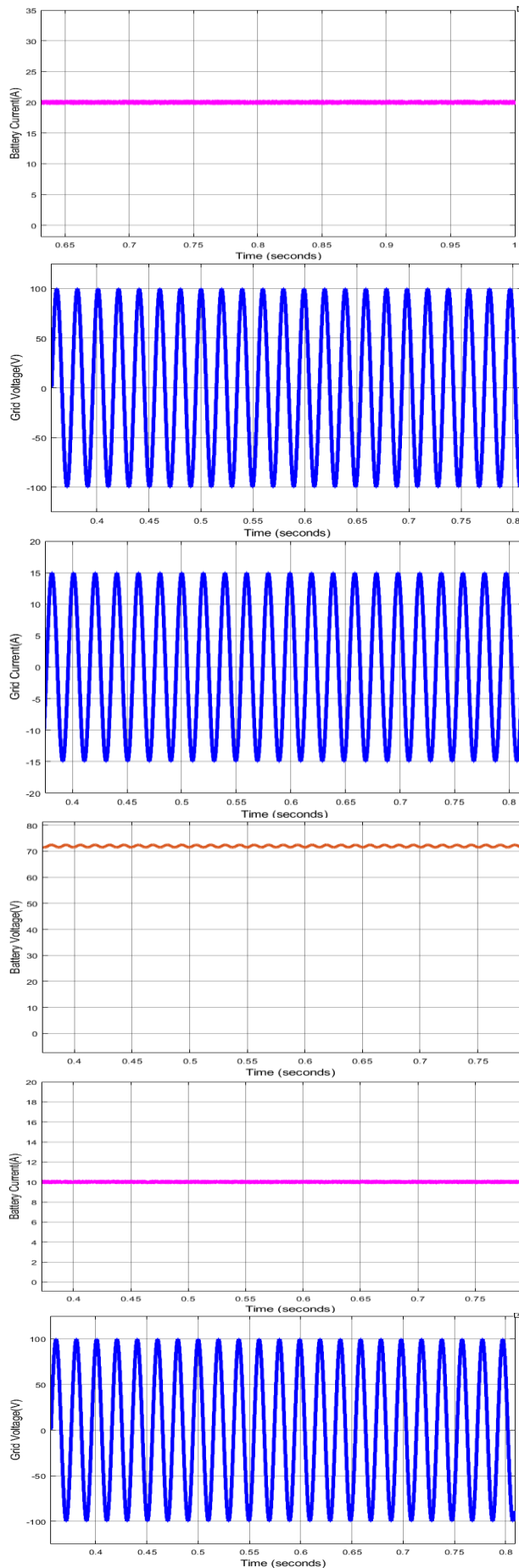
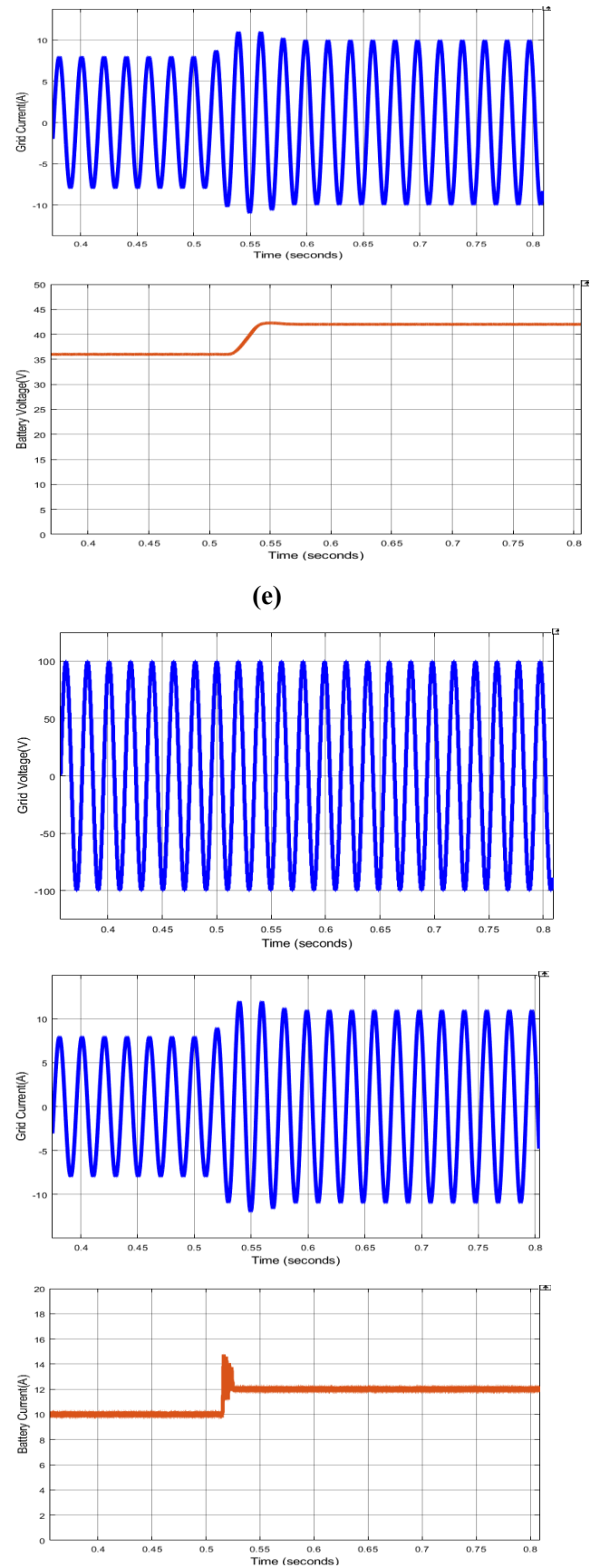


Fig.2 Control system with PI controller





(e)



(f)

Figure 6: Outcomes of the simulated study (a) The voltage at the battery terminals, the voltage at the grid, the current at the grid, and the voltage at the dc link on its own, (c) Charging two batteries simultaneously, (d) Alterations to the voltage and current controller references, (e) charging of two batteries in series, and (f) changes to the voltage sensor.

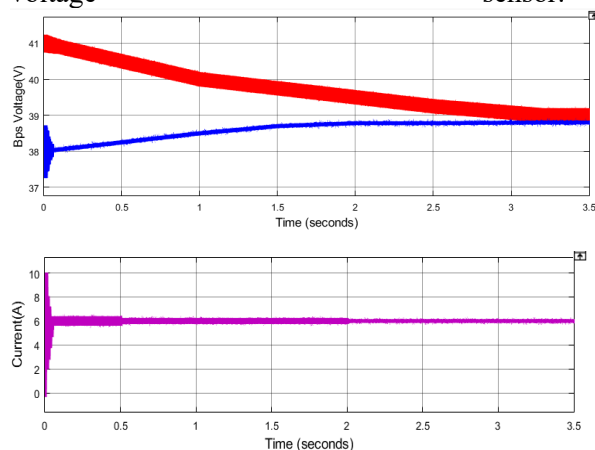


Fig. 7. Voltage balancing facility simulation results using BPs from various systems of components.

CONCLUSION

Two novel reconfigurable power converters, CBC and BSC, are proposed and studied in this study for use in battery-powered electric vehicles (EVs). To evaluate the converters' performance with the dual-battery electric vehicle, we may use an isolated EV charger (ICS). The reconfigurability of the converters has been shown via MATLAB simulations & hardware testing. This includes the ability to connect two batteries in parallel or series, as well as to use one battery while charging. The results and analysis demonstrate that the proposed converters enhance battery life and provide more flexibility by distributing the load across each BP. Among these converters' standout features is the ability to connect any BP on a resulting terminal. This enhances the electric vehicle's overall reliability and functional safety by making sure the power source system is modular. Before connecting the BPs in parallel, you may use the inbuilt power distribution mode of the conversions to make sure their terminal voltages are identical. Thus, circulation currents are decreased, and battery packs have a longer and more dependable life. Extensive simulations & hardware testing demonstrate the versatility and robust performance of the recommended converters, proving their effectiveness. All things considered, the proposed method is a promising first step toward combining

two different batteries for EVs; it may improve operating efficiency and flexibility while reducing worries about battery life and reliability. Prolonged battery life, continuous operation in the case of a power outage, and improved functional safety are additional benefits provided by the proposed reconfigurable design. Despite a slightly higher initial component cost, this strategy is more favorable and cost-effective for actual EV applications due to long-term cost reductions and system reliability.

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