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BIDIRECTIONAL DC-DC CONVERTER AND SMC CONTROLLER FOR ELECTRIC VEHICLE CHARGING

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Abstract: Increasing numbers of people are looking to purchase electric vehicles (EVs). Nevertheless, there are still issues that will need future attention, such as noticeable variations and noise in the output. While conventional hybrid automobiles have several advantages, HEVs mainly differ in that they are propelled by an electric motor rather than a gas engine. An energy storage device, such as batteries or the grid, provides the electricity that drives this motor. The electric motor may also store energy from the vehicle's regenerative braking system in the energy storage unit, thus it can double as a generator. In order to maximize energy savings, researchers studying vehicle energy conservation generally use a hybrid control technique. This helps to distribute the load evenly throughout various operating modes, such as while the vehicle is in operation. An electric vehicle (EV) design that incorporates a combined energy storage system is the focus of this article. To improve long-distance endurance and save costs, it introduces a new hybrid energy storage system. To govern the Li-ion battery's capacity and the supercapacitor's charge state, this research suggests a hybrid energy storage system that uses dynamic constraint constraints. Hybrid energy storage systems may obtain more precise and distortion-free outputs by adopting a Sliding Mode Control (SMC) controller This improves performance and efficiency.

Keywords: DC-DC converters, electric vehicles, and sliding mode control.

I. INTRODUCTION

It is impossible for India to meet its energy needs with its current petroleum reserves. In addition, fluctuations in the availability of imported natural gas and crude oil might affect it. [1] India still beats China and the United States, even though it has fallen to third place globally for overall oil imports. About 82.8% of India's total petroleum basket comes from crude oil imports, while about 45.3% comes from natural gas imports. [2] The air pollution problem has been made worse by the strong association between the use of petroleum products and air pollution, hence there has been a concerted attempt to reduce this use. The high cost of imported crude oil also has a significant impact on the Indian economy. As said before; to achieve these objectives, we must shift our energy consumption away from fossil fuels and toward nuclear power and green renewables. [4] There are a lot of factors that have contributed to the recent electrification of transportation, including the demand for additional energy and the need for economic development [5]. A varied fleet of electric locomotives was also useful to the railroads for a while. [6] Trains go from point A to point B using predetermined routes. Using pantograph slider slides makes receiving electric power from a conductor rail simpler. broadening the scope of the term, obtaining electricity in a similar manner to electric vehicles (EVs) is more challenging due to the extensive UTOPIA they provide. [7] One-way electric cars store energy is in their battery packs, which may be strong and have a lot of capacity. This allows them to go a long way before needing to be charged again. Despite several government subsidies, electric vehicles (EVs) continue to be priced out of reach for most buyers. To boost the percentage of the electric vehicle industry, tax credits and incentives from the government are crucial right now. [8] Invent inflated claims The biggest problem with EVs is their inability to store energy, which is mainly solved by batteries. However, batteries' short lifespan, high price, and low energy capacity have made them unaffordable. Developing a battery for an electric vehicle is challenging because it must meet many criteria at once: a high-power density, a long cycle life, a low price, a high level of safety, and durability. [9]. The public today views lithium-ion batteries as the best value for money when it comes to electric vehicle batteries [10]. Even though a whole pack of lithium-ion batteries used in EVs can hold 90-100 Wh/kg, the commercially available batteries can only hold 90-100 Wh/kg [11]. Compared to gasoline's energy density of over 12,000 Wh/kg, this estimate's energy density of about 300 Wh/kg is far lower. Pure electric vehicles (EVs) need a plethora of strong and costly batteries to get the same range as an ICE car, which is 300 miles. The most up-to-date data suggests that the average cost of a lithium-ion battery is about $500/kilowatt-hour (numbers) The National Highway Traffic Safety Administration estimates that, between the purchase price and annual maintenance costs, drivers of battery electric vehicles save an additional $1,000.

II. PROPOSED SYSTEM

The implementation is shown in this section. The battery values used are VES1 = 100 V and VES2 = 50 V. For the sake of clarity, the proposed BDC made use of a plethora of active power MOSFETs. The experiment only used PWM-controlled signals to switch six power MOSFETs.

The properties of the circuit are as follows: RL1=RL2=RL=50 mH, CB=10 mF, CH = 1880 mF, CES1=CES2=400 mF, ESR of inductances RL1=RL2=RL, ESR of capacitances RCB=20 mH, RES1=RES2=50 mH, and line resistances RES1=12 mH and RES2=6 mH.

A) The low-voltage dual-source powering mode is represented by the following equation:

a) State1 (to t1): During this time, the switches for Q1 and Q3 are turned on, while the switches for Q2 and Q4 are turned off.

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$$L_1 \frac{diL_1}{dt} = V_{es2} - V_{cb} \quad 1$$

$$L_2 \frac{diL_2}{dt} = V_{es2} \quad 2$$

b) State2(t1<t<t 2): During this Time period and Q1 and Q2 are Off and Q3 and Q4 switch are ON below are eq of voltage across L1 and L2

$$L_1 \frac{diL_1}{dt} = V_{es1} \quad 3$$

$$L_1 \frac{diL_2}{dt} = V_{es2} \quad 4$$

c)State3(t2<t<t3) : During this Time period Q1 & Q3 switch are ON and Q2 and Q4 are Off below are eq of voltage across L1 and L2

$$L_1 \frac{diL_1}{dt} = V_{es1} \quad 5$$

$$L_1 \frac{diL_2}{dt} = V_{es2} + V_{cb} - V_h \quad 6$$

d) State 4 (t3<t<t4): Time for duration period Q4 and Q3 switch are ON and Q1 and Q2 are Off below are eq of voltage across L1 and L2

$$L_1 \frac{diL_1}{dt} = V_{es1} \quad 7$$

$$L_2 \frac{diL_2}{dt} = V_{es2} \quad 8$$

B)Energy Regenerating Mode for High Voltage DC Bus:

a) State1(to<t<t 1): During this Time period Q1 and Q3 switch are ON and Q2 and Q4 are Off below are eq of voltage across L1 and L2

$$L_1 \frac{diL_1}{dt} = V_{es1} - V_{cb} \quad 9$$

$$L_2 \frac{diL_2}{dt} = V_{es2} \quad 10$$

b) State2(t1<t<t 2): During this Time period Q4 and Q3 switch are ON and Q2 and Q1 are Off below are eq of voltage across L1 and L2

$$L_1 \frac{diL_1}{dt} = V_{es1} \quad 11$$

$$L_2 \frac{diL_2}{dt} = V_{es2} \quad 12$$

c)State3(t2<t<t3) : During this Time period Q2 and Q4 switch are ON and Q1 and Q3 are Off below are eq of voltage across L1 and L2

$$L_1 \frac{diL_1}{dt} = V_{es1} \quad 13$$

$$L_1 \frac{diL_2}{dt} = V_{es2} + V_{cb} - V_h \quad 14$$

d) State 4 (t3<t<t4): Time period Q4 and Q3 switch are ON and Q2 and Q1 are Off below are eq of voltage across L1 and L2

$$L_1 \frac{diL_1}{dt} = V_{es1} \quad 15$$

$$L_2 \frac{diL_2}{dt} = V_{es2} \quad 16$$

It is possible to swap out the power MOSFETs (SES1 and SES2) with breakers that are suitable for the task. One other perk of adopting commercial ES1 or ES2 packs is that they often feature a built-in on/off switch for turning off the energy storage device. This means that future studies can do away with the need for SES1 and SES2 packs altogether. Figure 1 shows the MATLAB Simulink model implementation for electric car dual battery storage. Electric vehicle motor, two batteries, and a transistor network with bidirectional outputs make up the system.

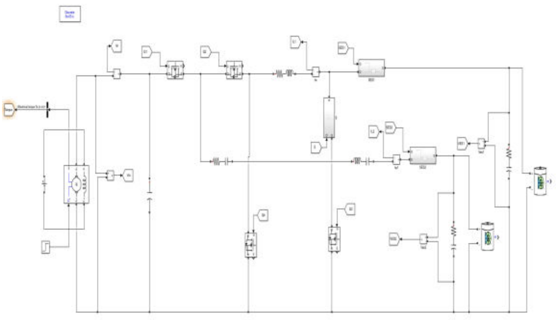

Figure 1: Model Implemented for Electric Vehicle

Figure 2 displays the SMC controller and the SPWM controller. The inputs to the SMC controller are the error and the change in error from the reference, whereas the Sine wave comparison is done via the repeated sequences.

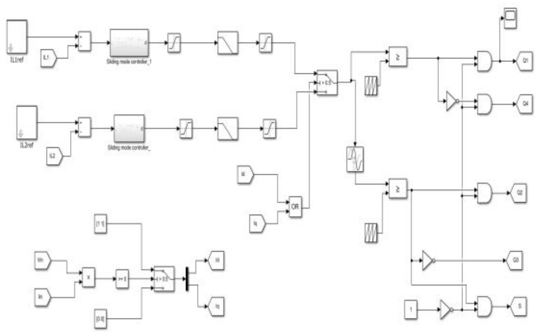

Figure 2: Proposed Control System for SMC and SPWM

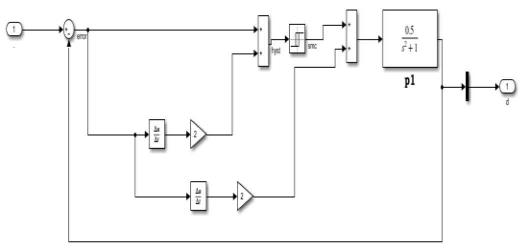

Figure 3: SMC circuit diagram

III. PROPOSED SMC CONTROLLER

One method of controlling switching is the sliding mode controller, or SMC. This method of control involves using a well-designed control rule to guide the system states toward a specified target surface, in this case a sliding surface, while keeping the system states on the body. Simple sliding mode control for quadrotors has been successful in the past, according to the literature. To stabilize the quadrotor's under-actuated subsystem with the aid of a PID controller, R. Xu and U. Ozguner suggested a sliding mode control. By handling parametric uncertainty, they confirmed that the controller was resilient. As a means of stabilizing the quadrotor, Swamp (2016) presented a Lyapunov-based second-order sliding mode control. When compared to the traditional sliding mode controller, this second-order model showed promise and guarantees resilience. As shown in Figure 4, a basic SMC

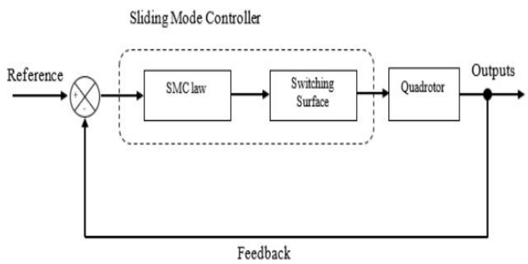

Figure 4: A block diagram of Sliding Mode Controller

The controller chart and flow of modes are shown in figure 5. Electric vehicles have several modes, including energy generation, dual source powering, boost, and buck. One part of the converter control structure is the vehicular energy, power, and voltage management unit. It chooses the BDC mode according on the vehicle's

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operating characteristics, such the power demand in different driving modes (Pdem) and the voltages from the two sources (VES1, VES2). As a result, the active switches (S, Q1Q4) may be controlled by SMC or more complicated methods based on the current references (iL1,ref or iL2,ref).

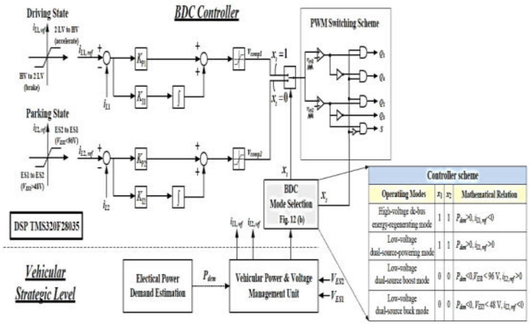


Figure 5: Flow of Modes and Controllers

IV.SIMULATION RESULTS

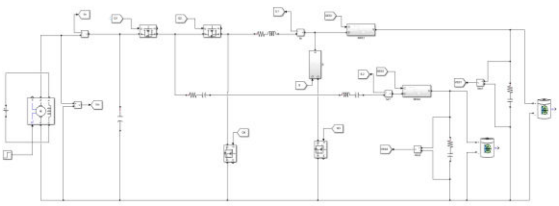
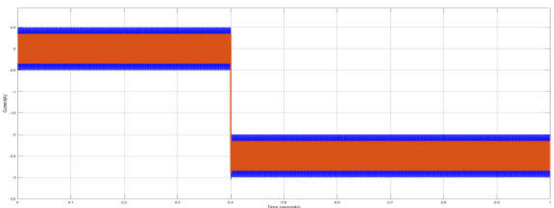
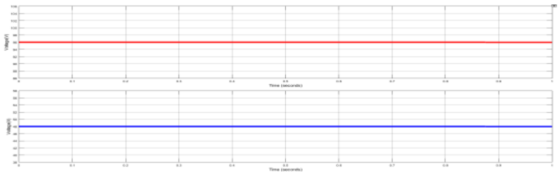


Figure 6: Model Implemented for Electric Vehicle

(A) EXISTING RESULTS



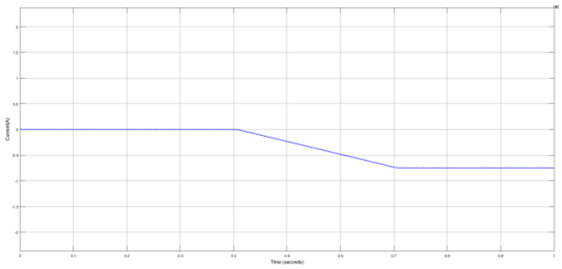
(a)



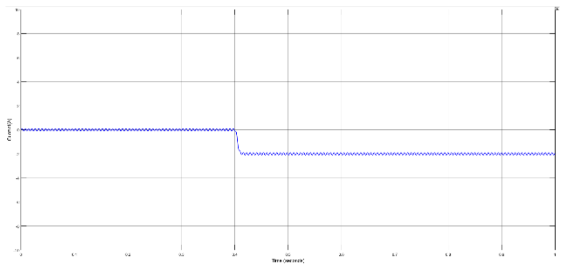
(b)

Figure 7: (a)Inductor Currents and (b)Battery Potential

The figure 7 represents, Inductor current and Battery potential demonstrating minimal fluctuations. The currents in the inductors iL1 and iL2, moved in the opposite direction relative to the applied power. The observed low-side and high-side output voltages were approximately 96V for VES1 and 48V for VES2.



(a)



(b)

Figure 8: Inductor Currents

Figure 8 illustrates, the inductor currents highlighting reduced fluctuations and seamless transitions during mode shifts. The currents corresponding to the two inductors, iL1 and iL2 are depicted.

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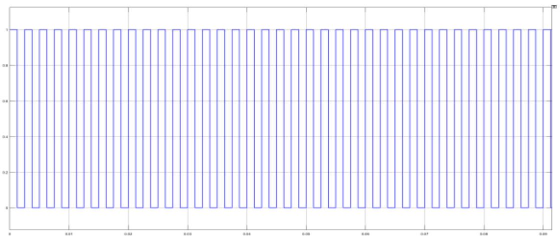

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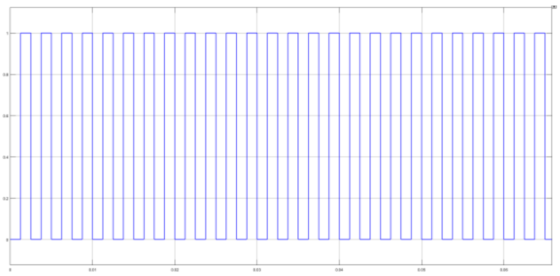

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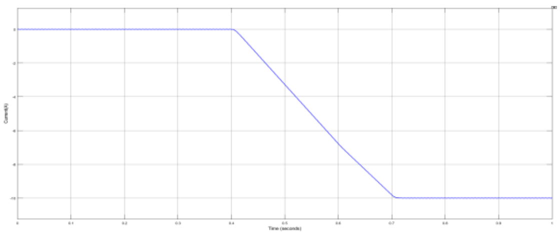
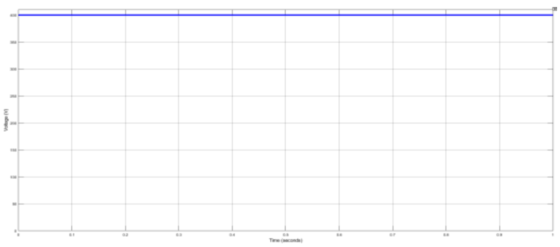


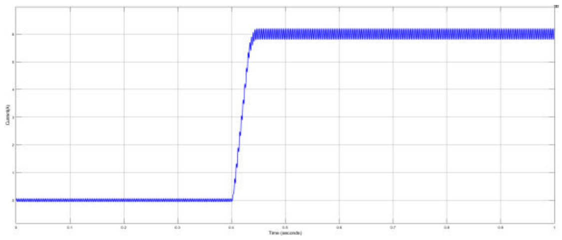
(c)



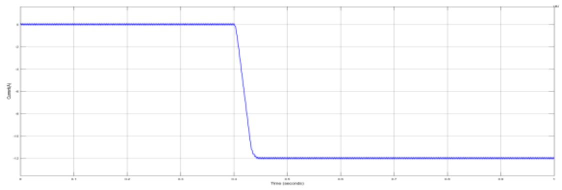
(d)

Figure 9: (a, b)Switching Pulses, (c)Inductor Current and (d)Motor Voltage

Figure 9 depicts the output waveforms, showcasing improved transitions and reduced distortions when compared to the PI controller. The shorter transition periods indicate smoother switching, which contributes to an extended lifespan of the electric vehicle.



(a)

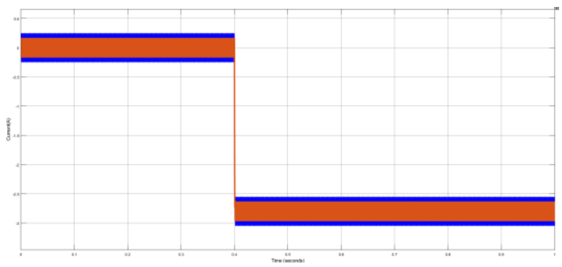


(b)

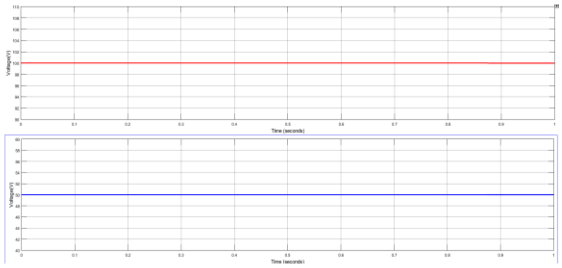
Figure 10: Final Inductor Current

In figure 10, The Final Inductor current transitions showcasing reduced distortions and smoother waveform patterns. The study's analysis indicates that the high-voltage DC-bus energy-regenerative buck mode, low-voltage dual-source powering mode, low-voltage dual-source boost mode (ES2 to ES1), and low-voltage dual-source buck mode (ES1 to ES2).

B) EXTENSION RESULTS WITH SMC CONTROLLER



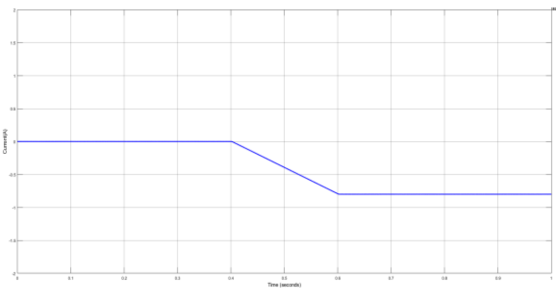
(a)



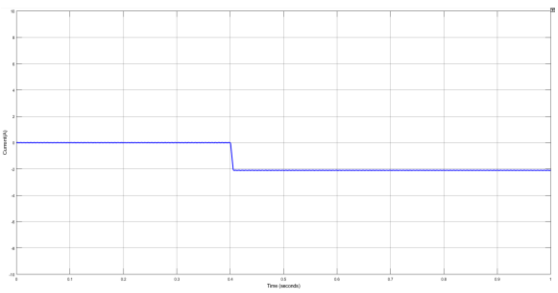
(b)

Figure 11: (a)Inductor Currents and (b)Battery Potential

In figure 11, Inductor current and Battery Potential demonstrating a stable profile with minimal fluctuations. The implementation of a sliding mode controller enhances performance, ensuring smoother operation. The currents within the inductors, iL1 and iL2, move in the reverse direction relative to the supplied power. In this configuration, the recorded output voltages are approximately 100V at VES1 (low-side) and 50V at VES2 (high-side), offering a more reliable and controlled energy transfer mechanism.



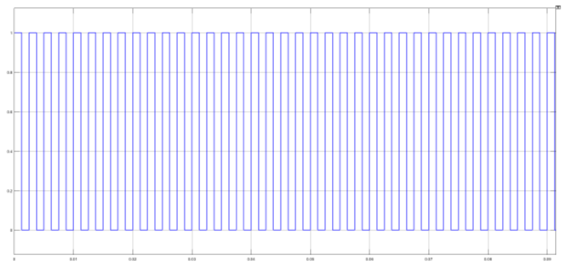
(a)



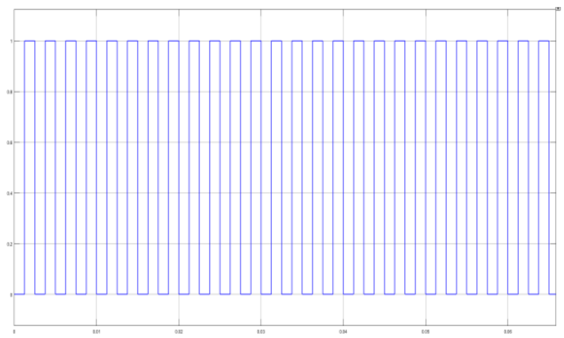
(b)

Figure 12: Inductor Currents

Figure 12 illustrates, the inductor currents revealing reduced fluctuations and smoother transitions during mode changes. The application of the sliding mode controller enhances stability, effectively minimizing variations. The currents flowing through the inductors iL1 and iL2 are depicted, highlighting improved dynamic response under different operating conditions.



(a)



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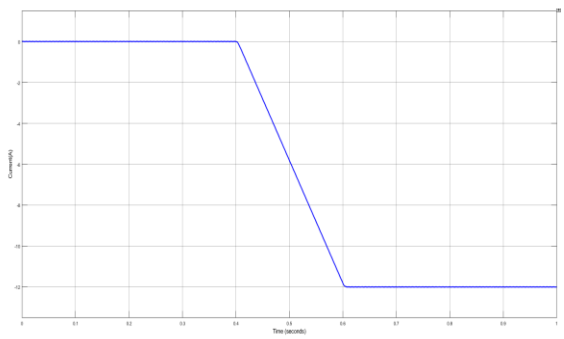
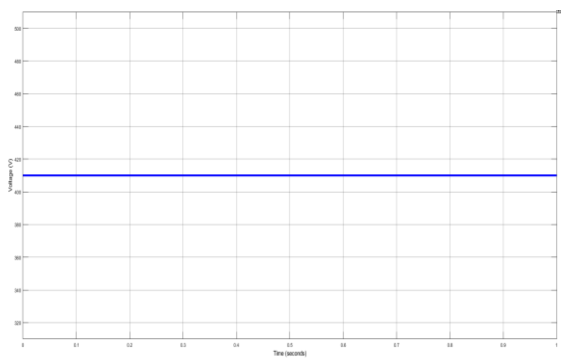


(c)



(d)

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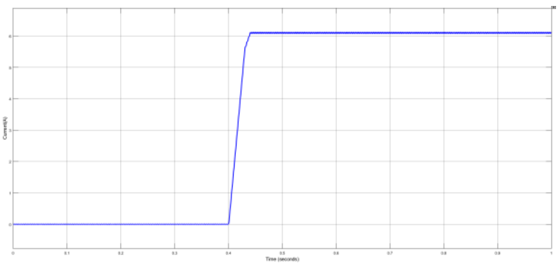
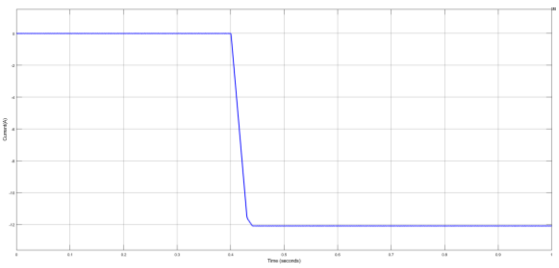
Figure 13:(a, b)Switching Pulses,(c)Inductor current and (d)Motor Voltage

The figure 13 presents, the output waveforms highlighting improved transitions and reduced distortions compared to the ANFIS Controller. The integration of the sliding mode controller enhances system stability, ensuring smoother switching operations. The reduced transition periods indicate efficient energy transfer, ultimately contributing to an extended lifespan of the electric vehicle.



(a)



(b)

Figure 14: Final Inductor Currents

In figure 14, the Final Inductor Current transitions demonstrating reduced distortions and refined waveform quality. The integration of the sliding mode controller optimizes system performance, ensuring precise control with minimal fluctuations. The study's analysis confirms that the high-voltage DC-bus energy-regenerative buck mode, low-voltage dual-source powering mode, low-voltage dual-source boost mode (ES2 to ES1), and low-voltage dual-source buck mode (ES1 to ES2) achieved impressive efficiency. The enhanced stability and improved energy transfer contribute to a more reliable and efficient operation of the system.

CONCLUSION

The promise of electric vehicles (EVs) to lessen our impact on the environment in terms of both energy use and emissions has garnered a lot of interest. Electric vehicles are becoming more competitive with conventional gas-powered vehicles as their prices continue to drop, which is good news for both manufacturers and governments looking to expand the electric vehicle industry. The increasing demand for electric cars is largely attributable to developments in lithium-ion battery technology. To make the switch to electric driving a reality, however, battery capacity must be significantly increased. Research on the ecological effects of EVs is ongoing, with a focus on the pollution that results from battery manufacturing. The greenhouse gas emissions associated with battery production have been the subject of recent research, the results of which have been mixed. Many refer to the energy storage system (ESS) as the "brain" of EVs since it controls the EVs' power, performance, and range. High energy density and peak capacity are necessities for the increasing demand for electric cars, and this can only be achieved via the efficient functioning of the ESS. In industrial applications, the ESS often incorporates both batteries and supercapacitors, which are renowned for supplying significant quantities of energy and power. This research presents a bidirectional DC-DC converter for usage in hybrid electric cars and analyses two different kinds of battery energy sources. Although an ANFIS controller adds certain useful features to this system, it also reduces the system's lifetime. The suggested study demonstrates that such energy storage devices have longer lifespans, higher precision, smoother transitions, and less distortion when coupled with a sliding mode control (SMC) controller and sinusoidal pulse-width modulation (SPWM). It is possible to implement a hybrid power architecture with the help of the suggested SMC controller-based bidirectional DC-DC converter in fuel cell/HEV systems. As far as needs and operating range are concerned, the system is up to far. Hardware implementation and further controller optimization, maybe with the help of a fitting function based on neural networks, might be part of future development.

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