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Single Switch DC-DC Converter for Battery Feed Electrical Vehicle

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Abstract: A new single-switch transformer less lift DC-DC converter has been suggested that energy component cars could benefit from a new single-switch transformer reduced lift DC-DC converter. The newly developed topology makes use of a different capacitor multiplier and an integrated LC2D yield organise in order to improve the voltage addition of the converter and reduce the voltage load that is placed on the force switch. In addition, the suggested converter features a broad voltage gain range, which allows it to accommodate a broad variety of voltage swings produced by the energy component. The operating standards of the suggested converter as well as its consistent state examinations are presented below. Recreation was utilised in the production of a scaled-down, exploratory model that had 800 V and 1 kW. The outcomes of the re-enactment demonstrate that the framework is sufficient.

Keywords: Single Switch, DC-DC Converter, Battery, Feed Electrical Vehicle

Introduction

Due to global efforts to reduce CO2 emissions and fossil fuel consumption and the falling cost of sustainable energy systems, vehicle electrification has received attention [1]. Electric vehicles (EVs) fueled by fuel cells are important in the clean energy vehicle market since they are zero-emissions [2]. It offers excellent output current density and efficiency. The fuel cell's output voltage drops significantly as the output current increases, a trait called "soft output characteristics [3-5]. Therefore, it can't power the EV's inverter directly. A step-up DC-DC converter is needed to connect the fuel cell and inverter's DC-LINK due to their voltage differences [6-11]. This DC-DC converter needs a common ground between its input and output ports to reduce EMI and maintenance safety hazards and a low input current ripple to extend fuel cell life. To handle the fuel cell's enormous voltage swings, the step-up DC-DC converter should have low input current ripple and wide voltage gain range. The step-up converter's input and output terminals should have a constant potential difference or common ground to avoid electromagnetic interference [12-17].

Conventional boost converters can theoretically gain limitless voltage at unity duty cycle. In practise, analogous series resistances of passive components and parasitic parts of active components reduce voltage gain at extremely high duty cycles [18-24]. The usual boost converter's efficiency drops drastically at severe duty cycle levels, and semiconductor devices experience voltage stress equal to the output voltage [25-33]. Many research have studied magnetically linked and uncoupled high step-up DC-DC converter topologies. Adjusting the magnetic coupling component's turn's ratio (coupled inductor, high-frequency transformer, or both) increases voltage gain and decreases semiconductor device voltage stress in step-up dc-dc converters [34-41]. This type of converter's main drawback is the magnetic coupling component's leakage inductance, which can create apparent EMI, high voltage spikes across transistors, and decreased DC-DC converter efficiency. Active clamp circuits or regenerative snubber circuits must be added to the converter circuit to recycle energy from the leakage inductance, but this increases complexity, size, and expense [42-49]. DC-DC converter topologies without magnetic coupling components are more efficient, cheaper, and easier to construct, hence they're popular. The three-level boost (TLB) converter was extensively analysed (half the output voltage) due to its low voltage stress on semiconductor devices [50-55]. This converter has a duty cycle limit of 0.5 and a potential differential between the input and output terminal grounds equal to HF PWM voltage, which may increase EMI [56-62]. A single-switch step-up converter that accepts a continuous current source and shares ground between its input and output terminals but has limited voltage gain. It was recommended that a high-voltage step-up converter with one switch and a common ground between input and output terminals be perfect. This converter has two big flaws: 1) Wildly changing input current. 2) Semiconductors are stressed at high voltage [63-71].

The converter cannot be used as a wide-input step-up converter since the minimum voltage gain increases with multipliers. For continuous input current, a dual-switch step-up converter was proposed [72-81]. The uk converter with active voltage multipliers underpins this converter's structure, which can adapt to future changes. However, this converter has high voltage demands on transistors and diodes and a high-frequency pulse width modulation potential difference between input and output terminal grounds [82-87]. Another dual-switch boost converter uses a switched capacitor network for high step-up gain [88-91]. This converter has high input current ripple, semiconductor component voltage stress, and no common ground between input and output terminals. Due to its high step-up gain, low transistor voltage stress, and shared ground with the input, a new voltage-lift boost converter was presented [92-101]. This converter's wide voltage gain range suits the fuel cell's mild output. These properties make the converter a promising option for connecting an EV's fuel cell to the inverter's DC link. This work uses the 800 V powertrain architecture to reduce power train wiring complexity [102-109].

Literature Review

Three energy sources—photovoltaic (PV) module, battery bank, and SRM—make up an SRM-based series-type HEV. To merge these three sources of electricity into one, you'll need a tri-port converter. The tri-port converter's compact design and modular architecture make it suitable for use in HEVs. Under driving conditions, the proposed tri-port converter allows for energy flow from the PV module to the SRM or the battery bank, and vice versa; under idling conditions, energy flow from the PV module to the battery bank or the SRM can be realised without the need for any additional converters. To complement these varied operational modes, relevant control strategies are also designed. Additionally, the tri-port converter's fault tolerance properties are studied to increase its practicability in demanding HEV application settings. The performance of the proposed tri-port converter for EV applications is evaluated through simulation and testing using a 750W prototype [110].

One of the most common types of motors used in PHET applications is the switched reluctance motor (SRM) because of its rear-earth free, strong starting torque, broad speed range, and good fault tolerance. To accomplish flexible energy conversion between the various electrical energy components on board, such as the PV module, battery bank, and motor, typically more than two converters are required. The trucks should be driven by high-power converters that take up little room in transit. For grid-connected charging, an additional converter is required. The complexity of the on-board power electronics converter is increased by all of these conversions. This research offers a modular tri-port high-power converter for SRM-based PHETs, which would allow for the consolidation of a number of separate electrical energy sources. The tri-port high-power modular converter allows for variable energy flow and parallel/series winding connections. Additionally, AC grid-connecting nodes are built in the drive, enabling the proposed converter to function as a grid-connecting charger without any supplementary infrastructure. The proposed converter and control mechanisms are validated for viability via simulation and testing [111].

Physical, energy, and State of Charge models are used in the method (SoC). A weighted average is used to calculate an average of the model results. This method ensures the function is always available and, more crucially, redundant. When the key is turned in the ignition, the driver is given a precise initialization range thanks to these techniques. This makes use of data from prior drives to predict an outcome for the current one. The work sequence of the EV range function is outlined. The results of analysing data from multiple driving cycles demonstrate that the system is effective at predicting the range of electric vehicles. The temperature management of lithium-ion batteries is one of the difficulties that users must overcome. Lithium-ion batteries function optimally between ten and fifty degrees Celsius. The health and lifespan of the battery depend on an efficient temperature management system. Predicting the battery's temperature accurately is the first step in designing an effective thermal management system. Purposefully estimating the thermal loss of the battery pack based on electric characteristics and experiments, predicting the temperature rise of the battery pack based on the test results of a single cell, and modelling the temperature gradients of the battery pack under different operating conditions are all parts of this paper's effort to assess the thermal management system of a lithium-ion battery pack intended for HEV applications [112].

Operation Mode:

For each of the three switching states, the converter's analysis labels the charging and discharging currents across the five capacitors (C1–C5) as iC1 ch, iC2 ch, iC3 ch, iC4 ch, and iC5 ch, respectively [113-117]. All five capacitors (C1C5) have zero ripple voltage. 3) There are no equivalent series resistances between the inductors and capacitors. The Pulse Generator component creates periodic square wave pulses. The output waveform is controlled by the block's waveform parameters, which include Amplitude, Pulse Width, Period, and Phase Delay. The graphic below illustrates the effects of these variables on the waveform (fig.1).

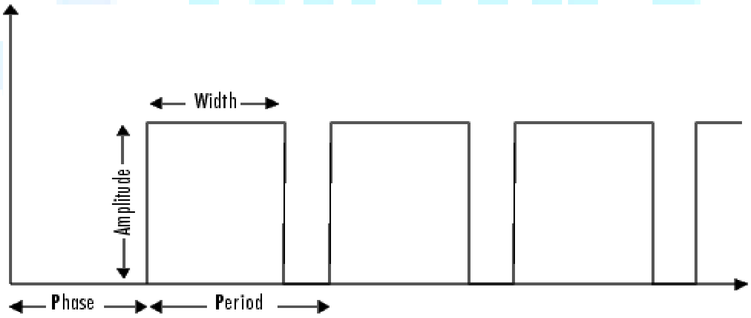
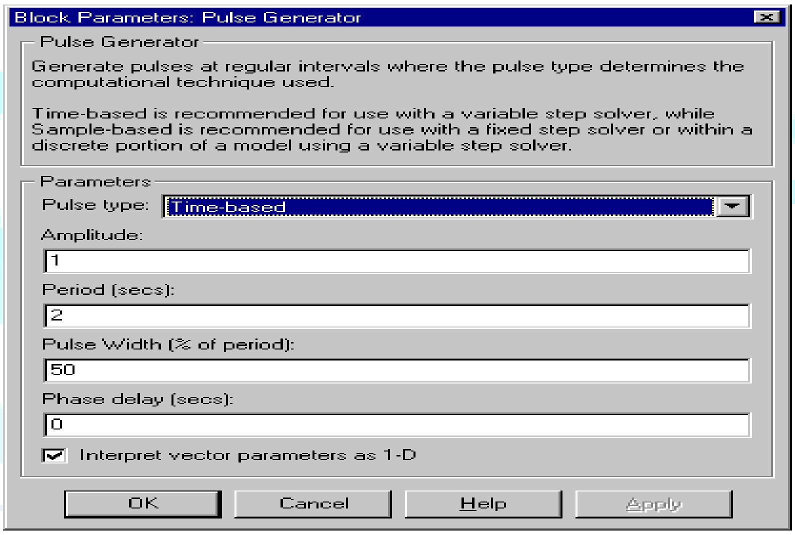


Figure 1: PWM modulation

The Pulse Generator can send out signals in the form of scalars, vectors, or matrices. The block can be made to generate a scalar signal by specifying the waveform parameters using scalars. Use vectors or matrices to describe the waveform parameters to have the block emit a vector or matrix signal. Each parameter in the waveform has an effect on its corresponding part of the output signal. For instance, the amplitude of the first pulse in a vector output is set by the value of the first parameter in a vector's amplitude parameter. After scalar expansion, all of the waveform's parameters should be the same size. The output has the same sort of data as the Amplitude input [118-121].

The block's output can be time- or sample-based, depending on the value of its Pulse-type parameter. If you choose sample-based, the block will only calculate its results at the intervals you specify. By choosing time-based, Simulink will only calculate the block's outputs at the moments when they actually change. The output of the block may require fewer calculations to calculate over the course of the simulation if this is the case. The pulse's waveform properties determine how frequently the block's output changes. Since the output of a time-based pulse generator is dependent on a number of variables, Simulink cannot use a single solver to calculate this value. For models with time-based pulse generators, Simulink allows you to specify a fixed-step solver. The time-based pulse generators, however, have their sample time computed statically by Simulink. The sample-based simulation is then applied to the time-based pulse generators [122-127]. Time-based blocks require that the phase delay and pulse period be specified in seconds. Sample-based blocks have a sample time that is specified in seconds using the Sample Time parameter, and the phase delay and period are specified in integer multiples of the sample time. Let's say, as an illustration, that you choose a sample time of 0.5 seconds. Let's say you set the frequency of the pulse to be every two seconds. To do this, set the Period parameter of the block to 4. In this section, the sample time is expressed in seconds. Only if the block uses sample-based pulses will this parameter be displayed. For more details, check out the section on Defining the Sample Time [128-131]. Take into account 1-dimensional values for vector parameters. Selecting this option causes the block to produce a scalar-expanded 1D signal (vector) if the other parameters are single-row or single-column matrices. Otherwise, the dimensions of the output match those of the other inputs (fig.2).


Block Parameters: Pulse Generator

Pulse Generator

Generate pulses at regular intervals where the pulse type determines the computational technique used.

Time-based is recommended for use with a variable step solver, while Sample-based is recommended for use with a fixed step solver or within a discrete portion of a model using a variable step solver.

Parameters

Pulse type: Time-based

Amplitude: 1

Period (secs): 2

Pulse Width (% of period): 50

Phase delay (secs): 0

☑ Interpret vector parameters as 1-D

Figure 2: Pulse generator block

This section's sampling duration is given in seconds. If the block's pulse type is sample-based, then this parameter will be displayed. For more details, read about Defining a Sample Duration. Consider the vector parameters to be one-dimensional [132-139]. When this switch is activated and the input and output matrices are both one-by-one, the block produces a scalar-expanded one-dimensional (1D) signal (vector). In all other cases, the dimensions of the output and the other parameters are same (fig.3).

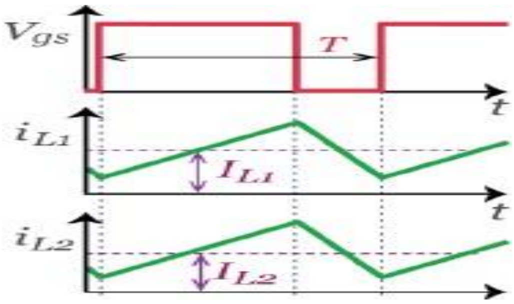


Figure 3: switching using pulse generation

IGBT

As it was refined, the insulated-gate bipolar transistor (IGBT) came to combine high efficiency and fast switching; it is a three-terminal power semiconductor device principally used as an electronic switch [140]. It is used in a wide variety of devices that require the switching of electric power, including variable-frequency drives (VFDs), electric vehicles, trains, lamp ballasts, air conditioners, and even stereo systems with switching amplifiers. The insulated-gate bipolar transistor (IGBT) is a semiconductor device with a metal-oxide-semiconductor (MOS) gate structure and four alternating layers (P-N-P-N) without regenerative action [141-146]. It is used in amplifiers to synthesise complex waveforms via pulse-width modulation and low-pass filters due to its fast on/off switching. If the device is being used as an analogue audio amplifier, its switching pulse repetition rate is likely to be at least ten times higher than the highest audio frequency it can handle (fig.4).

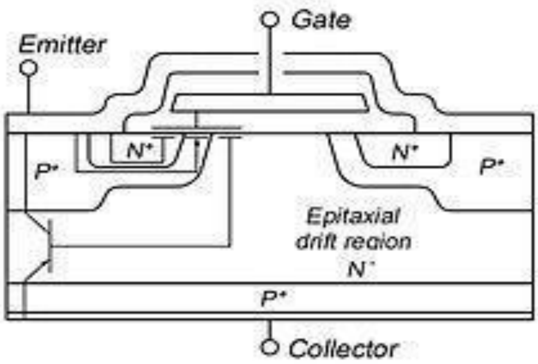


Figure 4: Cross section of IGBT

A minority-carrier device with high input impedance and high bipolar current-carrying capacity is the Insulated Gate Bipolar Transistor (IGBT). To many engineers, an IGBT is just a voltage-controlled bipolar device with a MOS-like input and a bipolar output (fig.5).

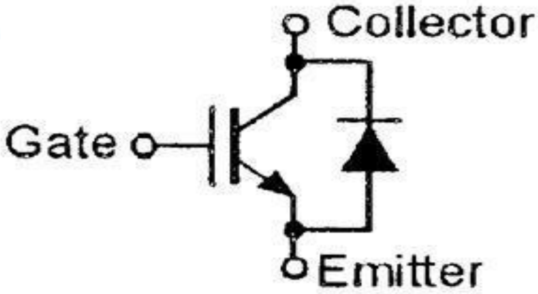


Figure 5: Symbol of IGBT

In a typical IGBT cell, the n+ drain is swapped out for a p+ collector layer, turning the device into a vertical PNP bipolar junction transistor. This supplementary p+ area forms a cascade connection between the surface n-channel MOSFET and a PNP bipolar junction transistor. The IGBT combines the high current and low saturation voltage capacity of bipolar transistors with the easy gate-drive properties of metal-oxide-semiconductor field-effect transistors. The IGBT is a single device that incorporates a bipolar power transistor and an isolated-gate FET for the control input. Medium- to high-power uses for the IGBT include induction heating, traction motor control, and switched-mode power supplies. Powerful IGBT modules can block voltages up to 6500 V and handle currents in the hundreds of amperes thanks to their parallel design. Hundreds of kilowatts of power can be managed by these IGBTs (fig.6).

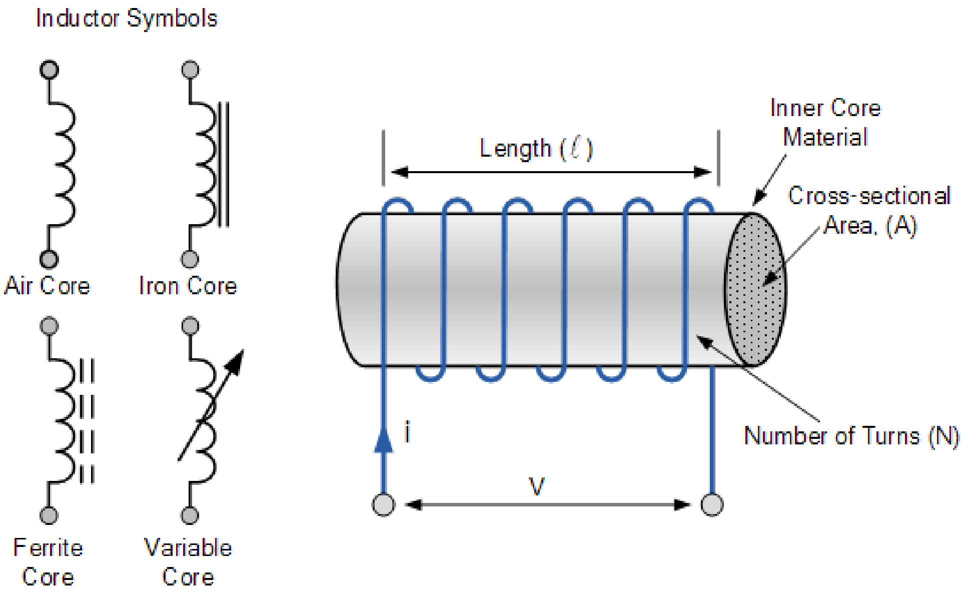


Figure 6: Inductor

To keep energy in the form of a magnetic field, an inductor is a passive electrical component. An inductor is a coil of wire in its most elementary form. The inductance of a coil increases as the number of turns increases. The inductance of a coil is affected by its diameter and the material it is wound in. In general, the inductance of a coil is minimised when an air core is used. For inductor winding, dielectric materials including wood, glass, and plastic are interchangeable with air. For a given number of turns in a coil, ferromagnetic materials like iron, laminated iron, and powdered iron produce higher inductance values. Increases of this magnitude have been observed in some circumstances. The importance of the core's form cannot be overstated. The inductance of a toroidal (doughnut-shaped) core is greater than that of a solenoid (rod-shaped) core of the same material and number of turns. The Henry (or "H") is the conventional measurement for inductance. Quite a large unit, this. Commonly used units include the microhenry (H), where 1 H = 106 H, and the millihenry (mH), where 1 mH = 103 H. It's not uncommon to hear the term "nanohenry" (nH), where 1 nH equals 109 H. Adding inductors to IC chips is a challenging fabrication process. In most microcircuit implementations, inductors are unnecessary and resistors can be used instead. Sometimes, inductance can be mimicked by a simple electronic circuit built using IC-fabricated transistors, resistors, and capacitors. Capacitors and inductors work together in many forms of wireless communication. Discrimination against noise can be achieved by connecting an inductor in series or parallel with a capacitor. Large inductors are commonly found in the power sources of computers and other electrical devices. The inductors in these setups serve to filter out any noise from the rectified utility AC, resulting in clean, battery-like DC.

A diode is a one-way current-conducting electrical component with two terminals (as long as it is operated within a specified voltage level). The resistance of a perfect diode will be 0 in one direction and infinite in the other. However, diodes cannot realise zero or infinite resistance in practise. To allow current to pass, a diode instead has extremely low resistance in one direction and very high resistance in the other (to prevent current flow). A diode performs the same function in an electrical circuit as a valve. These diodes do not allow current to flow in the forward direction (the "low resistance" direction) until a specified threshold voltage is reached. When current flows forward through the diode, we say that it is "forward biassed." When a diode is "reverse biassed," it is linked in a circuit so that its resistance is highest in the opposite direction. For a given range of reverse voltage, a diode will only stop current flowing in the opposite direction (when reverse biassed). When you get up here, the inverse wall gives way. "Reverse breakdown voltage" refers to the point at which this breakdown occurs. Diodes are able to conduct electricity in the opposite direction (the "high resistance" direction) when the voltage in the circuit is greater than the reverse breakdown voltage. This is why we don't actually mean "diodes have infinite resistance" when we say they have a large resistance in the reverse direction. The simplest type of semiconductor diode is a PN junction. When subjected to a forward bias, this PN junction acts as a short circuit, and when subjected to a reverse bias, it acts as an open circuit. Diodes are devices with two electrodes, hence the name.

Simulation Results

The use of simulation in business and research has made it a strong tool. Understanding simulation and its many uses is now crucial for any electrical engineer. One of the finest ways to investigate the behaviour of a system or circuit without really destroying it is through simulation. Engineering experts might purchase simulation tools for a variety of applications. Numerous sectors invest much in simulations before physically creating their goods. Research and development (R&D) projects typically rely heavily on simulation. It is essentially impossible to move forward without simulation. It is important to highlight that in power electronics, a laboratory proof of concept hardware prototype complements computer simulation. However, virtual prototypes created in a computer should not replace physical ones. Transformers, power lines, machinery, and power electronics are only some of the power system components represented in the libraries. These models are well-established in the academic literature and have been tested and validated by the Power Systems Testing and Simulation Laboratory at Hydro-Québec, a major Canadian utility serving the entire North American continent, as well as by researchers at Ecole de technologie supérieure and Université Laval. Demo files showcase the possibilities of Sim Power Systems for modelling a standard electrical system. There are additional self-learning case studies available for users who need a refresher in power system theory.

Optocouplers

It is often necessary to send signals and data from one subsystem within a piece of electronic equipment to another, or from one piece of equipment to another, without physically connecting them. This is typically the case when the voltage levels of the source and the destination are vastly different; for example, when a microprocessor running on 5V DC is used to drive a TRIAC switching 240V AC. To prevent overvoltage damage to the microprocessor, the connection between them must be severed in such cases. This isolation can be provided by relays, but even miniature relays are typically quite large in comparison to ICs and many of today's other miniature circuit components. Relays are not as dependable ó and can only operate at relatively moderate speeds because they are electro-mechanical.

Optocouplers combine two separate devices into a single, compact IC package, with one end acting as a transmitter for light (usually a gallium arsenide LED) and the other end acting as a receiver for the light (commonly a phototransistor or light-triggered disc). A translucent barrier separates them; it doesn't allow any electricity to flow through, but light can still pass through. Transfer efficiency, typically expressed as current transfer ratio (CTR), is the most critical specification for most Optocouplers. This is simply the ratio of the change in current through the output transistor to the change in current through the input LED. Devices employing a phototransistor as the output typically have CTR values between 10% and 50%, while those with a Darlington transistor pair can achieve values of up to 2000% or so. However, in most gadgets, CTR varies with absolute current level. It typically reaches a maximum at a current level of around 10mA for an LED and decreases at lower and higher currents. In addition to the input LED's maximum current rating IF (max) and the output transistor's maximum collector-emitter voltage rating VCE (max), the Optocoupler's bandwidth ó determined primarily by internal device construction and the performance of the thyristor ó determines the highest signal frequency that can be transferred through it, and the Optocoupler's minimum value for its series resistor.

LEAD Acid Battery

The battery is a lead acid battery, which means it employs sponge lead and lead peroxide to transfer chemical energy into electrical power. Because of its lower price and higher cell voltage, the lead acid battery is widely utilised in power plants and substations. Listed below are the primary constituents of a lead acid battery. The lead acid battery's primary components are the case and the plates. The plates inside the container transform chemical energy into electricity, which is then stored in the container. To prevent electrolyte discharge, lead acid batteries have a sealed container constructed of glass, lead-lined wood, ebonite, the hard rubber of bituminous compound, ceramic materials, or moulded plastics. The negative plates lie on two of the four ribs at the bottom of the container, whereas the positive plates rest on two of the ribs. The plates are supported by the prism, which also prevents a short circuit from occurring between them. The container material used for batteries must be stable in the presence of sulfuric acid, not easily deformed or porous, and free of contaminants that would otherwise harm the electrolyte. Plate - The plate of the lead-acid cell can come in a variety of shapes and sizes, but it always consists of a grid of lead and active material. The grid is necessary for the safe and uniform distribution of electric current throughout the active material. If the current is not delivered evenly, the active material will become unfastened and fall out (fig.7).

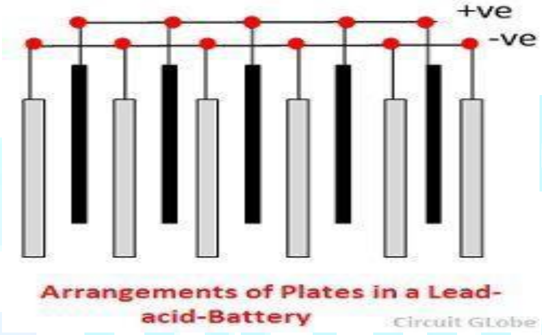
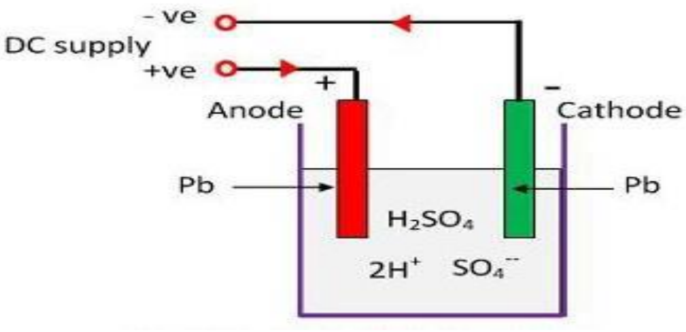


Figure 7: Plates

The grids are built from a lead-antimony alloy. Transverse ribs that cut across the areas at right angles or on the diagonal are a common feature of these. Both the positive and negative plates use grids, although while both are of the same general design, the grids for the negative plates are thinner since they are less crucial to the even conduction of the current. The battery has two distinct types of plates. The formed plates, plate plates, and pasted/faure plates all fit this description. Since Plante's plates are bulkier and more expensive than pasted plates, they are often reserved for usage in permanently installed batteries. The plates, on the other hand, are more robust and less likely to lose their active material due to repeated charging and discharging. The plant plate is weak in terms of its ability to hold food.

Working Principle

Sulfuric acid molecules dissociate into free-moving positive hydrogen ions (2H+) and negative sulphate ions (SO-) during dissolution. Hydrogen ions are positively charged and will migrate toward the electrodes and the negative terminal of the DC supply if the electrodes are submerged in solutions and the supply is turned on. The positively charged electrodes were attracted to the negatively charged SO—ions (i.e., anode). After gaining an electron from the cathode and two negative ions from the anodes, hydrogen ions combine with water to produce sulfuric acid and hydrogen hydroxide, respectively. The above equation describes the formation of lead peroxide from lead oxide and oxygen (PbO2.) So, when charging, the lead cathode stays lead, but the lead anode turns into lead peroxide, which is a chocolatey brown. With the DC power source cut off, the voltmeter can be used to measure the potential difference between the electrodes. By connecting the electrodes with a wire, the cell can provide electrical energy by allowing current to flow from the positive plate to the negative plate in an external circuit (fig.8).



Conclusion

In this research, a novel single-switch step-up DC-DC converter for use in fuel cell vehicles is proposed. This converter makes use of a switched-capacitor multiplier and an integrated LC2D output network. The suggested converter features a broad voltage gain range, which allows it to accommodate the fuel cell's broad voltage swings. Because the suggested converter places less than half of the output voltage's worth of voltage stress on the semiconductor devices, it is possible to use a power switch that has a lower rated voltage. Additionally, there is a low ripple in the input current, and the potential difference between the grounds of its input and output terminals is a constant voltage. Both of these characteristics contribute to the fuel cell having a longer lifetime and emitting less electromagnetic interference (EMI).

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