Article

Single-switch PWM converters for DC-to-DC power with reliability tolerance for battery power purposes

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Abstract: The functioning of fault-tolerant boosted conversions in both good and bad circumstances is covered in this work. The majority of our power plants and automotive applications make extensive use of surge conversions. Every component in a converter is accountable for causing one of the many problem kinds that affect the converter. In order to construct a tolerant of faults DC-DC converter, the reaction of the single switch DC-DC converter under various potential failures was examined. Utilizing a MATLAB Simulink approach, the response of each device across both typical and various potential fault scenarios was derived. The booster converter can also undergo additional heat research to determine how the converters react at various temps.

Keywords: tolerance for faults; fault evaluation; DC supply; charging batteries; DC to DC converters

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1. Introduction

Scaling either up or down the input voltage as well as controlling the DC voltage are the two functions of the DC-DC converters. DC-DC converters that operate with a single switch are typically used in recharging purposes. A power supply plus a DC-DC converter makes up a typical charging system. The dc-dc converter's input needs to be lossless in order for the system to charge effectively [1, 2]. To enhance the charging system's efficiency, a wideband dc-dc converter has to be properly designed.

Faults that are caused by external as well as internal variables can account for a portion of the charging system's issues. Short circuit and open circuit defects in the electrical system are the primary causes of internal faults [3, 4]. The primary causes of external faults include spikes in temperature across the system, rapid increases in earth fault current, or issues with anchoring.

When designing dc-dc power converters using pulse width modulation (PWM), fault analysis is crucial [5]. It provides us with comprehensive information about the potential harm and aids in our understanding of the severity of different fault types. It provides us with precise details regarding the highest resist durability of each part of a converter. It is quite helpful to us while constructing the converters to operate within their maximum capabilities. In this section we measure the converter's performance after introducing various flaws [6]. Anything in the circuit could have a fault; in this case, we'll be looking at the switch between [7-10], diode, inductor, capacitor, and load. Therefore, we have examined several defects in each of the converter's components in this research and have offered a comparison of the single switch dc-dc converter's efficiency. An effective fault tolerant single switch dc-dc converter might be constructed for a variety of purposes by taking into account the reaction of the converter during diverse failure scenarios.

2. Materials and Methods

2.1 Overview of the System

Depending on the purpose, the single switch dc-dc converter can be utilized to increase or decrease the input voltage. These are a few examples of popular single switching dc-dc converters that are employed in a variety of real-world scenarios. In this study, we analyze the efficiency of a boost converter. The boost converter schematic is displayed in Figure 1. A voltage at the output that is higher than the input voltage in a switch mode DC to DC converter is called a boost converter. The charging and discharge process of an inductor is the foundation of the boost converter's primary operation. It is resistant to abrupt input modifications [10, 11]. The resultant value is equivalent to the input voltage while the toggle switch is off, and the inductor charges (i.e., stores energy as a magnetic field) and releases it if the switching is active.

2.2 Variables for Modelling

The load's variables are displayed in Figure 1. We tested the converter in this study by using a battery as the load. DC-DC converters are typically employed in battery charging scenarios. Therefore, for the battery to be charged effectively, an efficient charging mechanism is always essential. Based on the simulation findings of the converter linked to the battery, a comparison has been done to determine which single switch dc-dc converter is most effective in recharging a battery under both typical and abnormal conditions.

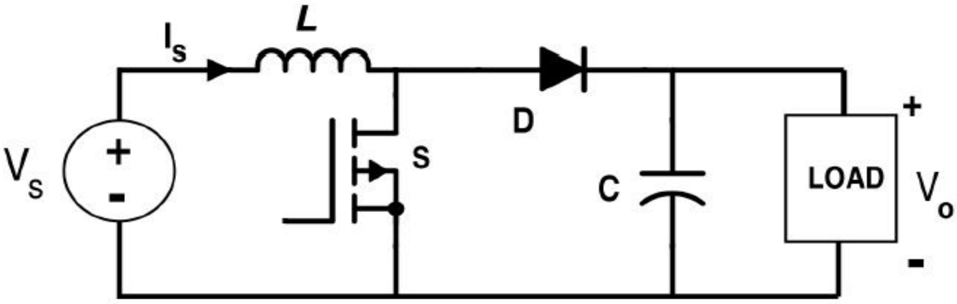

Figure 1: Boost converter circuit diagram

The converters are examined for various open and short circuit problems, and the efficiency of the converters is used to determine the outcomes. A short circuit fault at the switch itself results in extremely high current flowing via it and a rise in the temperature throughout the device, both of which lower the converter's effectiveness. While the move in the converter is open circuited, the inductor charges continuously and loses its magnetic property over time. Prior research has addressed these issues and provided strategies to identify and lessen switch faults [12-14]. Other components of the converter, such as the diode, inductor, and capacitor, may experience the same open or short circuit issue. These errors undoubtedly lessen the charging system's efficacy, and some of them have the potential to harm the circuit's components by abruptly increasing voltage or current. These errors are displayed below after being examined with the MATLAB Simulink programmed [15].

2.3 Dc-Dc Converter with Single Switch Tolerance for Faults

The purpose of a fault-tolerant booster converter is to completely eliminate all potential flaws in a circuit. The error is detected and mitigated by a device called a controller. The circuit's magnet element is mostly utilized to detect errors. Here, the type of problem is identified by taking into account the voltage generated by the inductor.

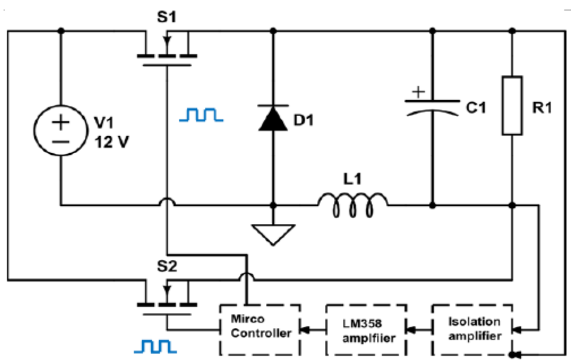

Figure 2(a) Boost conversion with fault tolerance

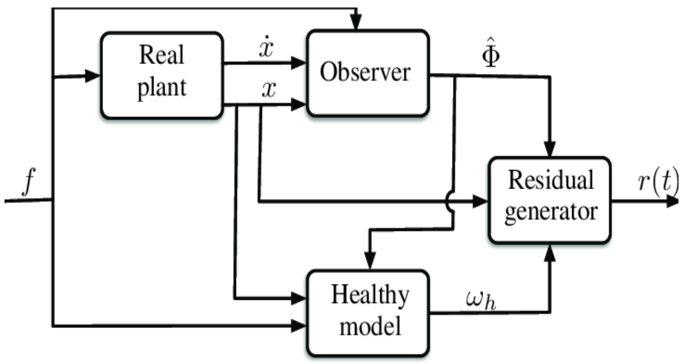

Figure 2(b) Circuit diagram for identifying faults

The fault tolerant boost converter is depicted in Figure 2(a). To safeguard the circuit's electronics from excessive current flow, a fuse wire is attached in close proximity to the load and supply. Normally, depending on the duty ratio, the voltage between the inductor will rise and discharged. However, the inductor typically loses its magnetic characteristic following the malfunction. As a result, the inductor voltage waveform acquired following the fault will undoubtedly differ from the waveform obtained during normal operation. The inductor's waveform is displayed in Figure 3(b) when it is operating normally, when there is an open circuit issue with the diode. We can see a distinct variation in the waveform during ordinary and fault scenarios when we examine Figures 3(b). The voltage across the inductor either rises to an extremely high level or falls to an extremely low level in open and short circuit problems. An error signal is formed through the comparison of both of these messages, and the controller processes it from there.

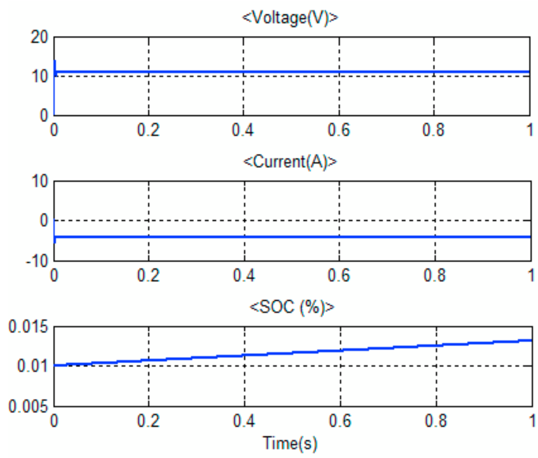

Figure 3(a) Battery production of boost converter in standard process

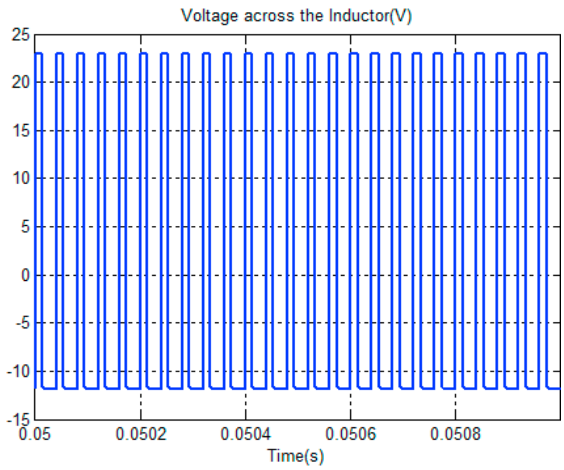

Figure 3(b) Voltage around the inductance

Figure 2(b) Displays the fault detecting circuit's block schematic. The voltage across the inductor under typical operating conditions is known as the standard inductor voltage. The voltage over the inductor under present conditions of operation is the real inductor value. If both signals have identical magnitude, the comparator's output is one; when the signals have different magnitudes, the output is zero. The comparator signal that is provided to the circuit breaker powers the controller. The controller triggers the circuit breaker to allow current to flow via the main switch or the extra switch, depending on whether the operational situation is normal or unusual. Figure 4(a) Displays the battery output when the controller is operating. The expanded waveform displays the controller's position in operation. Figure 4(a) clearly shows the brief shift in battery output that occurs for a few milliseconds at 0.5s when the fault occurs. The battery's performance will not be impacted by the slight decrease in output. In this case, the controller starts working right away after the error.

The output waveforms of the single switch DC-DC converter are displayed in Figure 4(b) under both failure and typical circumstances. In this case, the fault happens at time 0.5s, and the shape of the waveform shows that the output waveform stays constant even after the fault. The controller detects the malfunction right away and modifies the converter to maintain a steady output even following the malfunction.

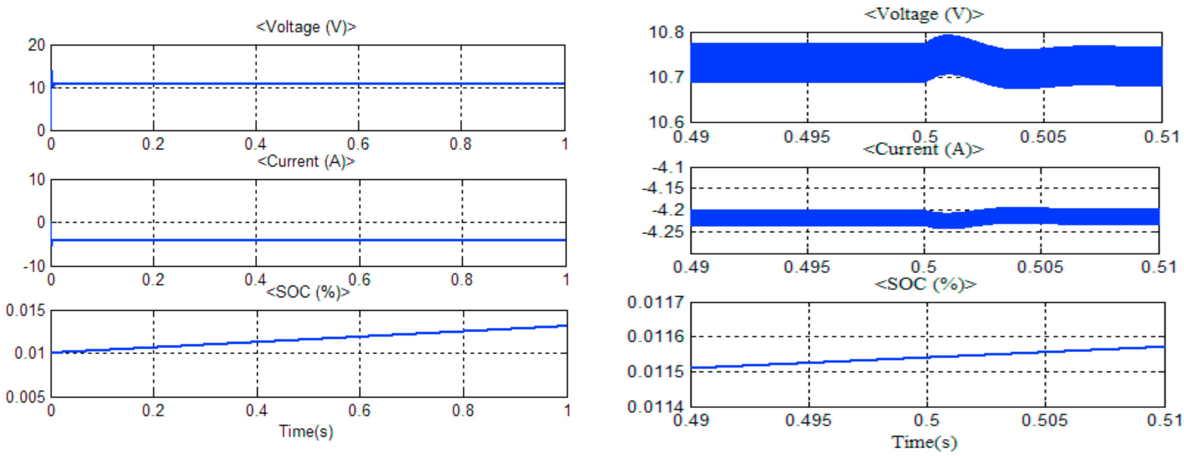

Figure 4: The resilient boost converter's battery power (**a**) in fault situation (**b**) in controller conflict

3. Results

The outcomes of simulations will provide a good understanding of the regular and fault situations of the converters' operation. Buck and boost conversions are the most often utilized single switching converters in charging situations. A fault-tolerant boost converter that can withstand frequently occurring converter defects is created by projecting the boost converter's outcomes under both normal and defective situations.

The efficiency of the booster converter under typical circumstances is displayed in the waveforms that follow. Figure 2(a) Displays the battery's voltage, current, and charge level in a typical situation. The battery voltage and current measured are in close proximity to the values mentioned in Figure 1. Figure 2(b) Displays the voltage waveform through the inductor. calculating the duty cycle worth, we are able to see that the inductor charges and discharges properly.

The switch's voltage and current wave is displayed in Figure 5(a). It is easy to see why the waveform depicts the voltage across the toggle switch in the neutral state and the current that passes across the device in the on state. The diode's typical operating voltage and current waveforms are displayed in Figure 5(b). The diode's current and voltage attain a value that is closer to the specified values once the toggle switch is turned on as well.

The waveform of the voltage across the capacitor under typical conditions is depicted in Figure 6. The output voltage and the voltage over the capacitor are identical.

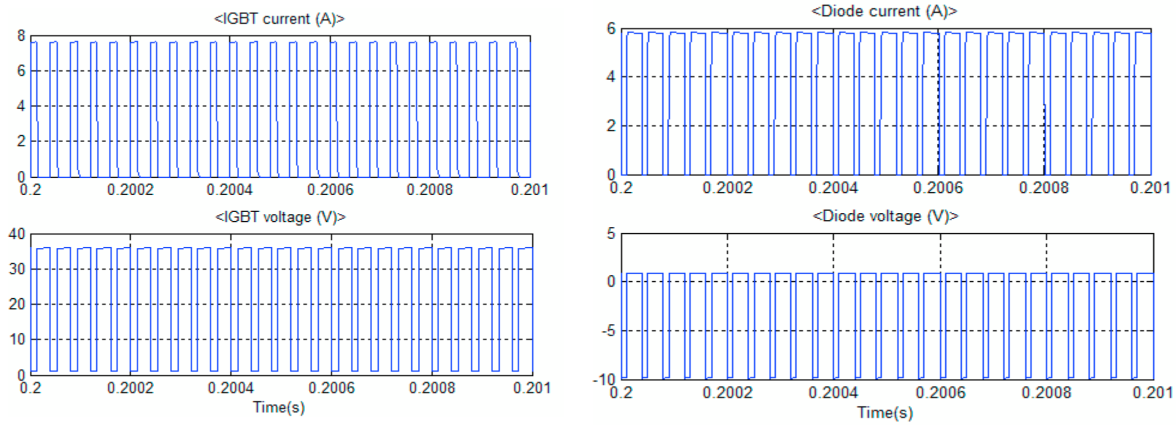

Figure 5(**a**) Current and Voltage at the switch (**b**) The waves of current and voltage at a diode.

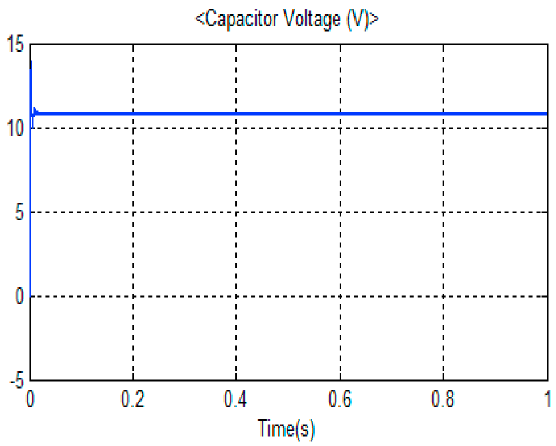

Figure 6: Capacitance Voltage

Table 1. Summit rates for various factors in Diode open circuit error in Boost converter

Inductor		Switch		Capacitor
Voltage(V)	Current(A)	Voltage(V)	Current(A)	Voltage(V)
-149	0.099	149	0.099	-0.255
Diode		Battery		
Voltage(V)	Current(A)	Voltage(V)	Current(A)	SOC
0.79	0	-0.255	0	NC

Open circuit diode

The highest values across a range of variables after an open circuit fault across a diode are displayed in Table 1. Following the fault, the voltage across the switch and inductor rises to an extremely high amount. The voltage's amplitude indicates how serious the fault is. As a result, an open circuit diode can quickly harm its switch and inductor. Figure 7(a) Displays the boost converter's battery settings in the event of a diode open circuit problem. It is evident from the pattern that the output voltage drops to an extremely tiny amount and the output current hits zero. As a result, battery charging becomes less effective. Similar to this, when a diode is open circuited, other converters' ability to charge a battery is diminished. Figure 7(b) Demonstrates that the voltage across the inductor only reaches aberrant peak levels when there is an enhanced converter diode open circuit malfunction. When the problem occurs, the voltage reaches its maximum value (in this case, it occurs at 0.5 seconds). These extremely high peak voltages have the potential to seriously harm the inductor.

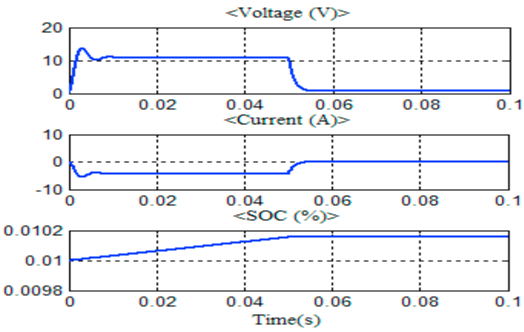

Figure 7(a) Open circuit diode

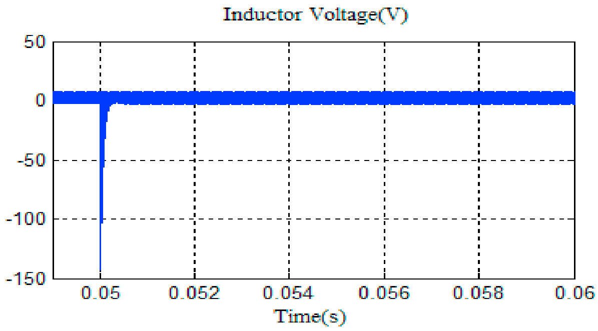

Figure 7(b) Inductor voltage in boost converter

Flip Open The circuit

The peak values of multiple parameters after an open circuit failure for the boost converter are displayed in Table 2. The table shows that there isn't an interruption in the battery charging process and that the output voltage reduces by just a couple of volts. The inductor loses its magnetizing ability when there isn't a pathway for it to departure, which is the sole issue in the event of a switch open circuit defect. The voltage over the inductor drops to zero when the current through the inductor stabilizes. After a malfunction, the converter will not do any boosting action; instead, only the input will be supplied to the outputs no changing activity.

Short Circuit Failure in Switches

The switch itself experiences constant, extremely high current flow whenever it is shorted. This will raise temperatures throughout the gadget and have an impact on how well it works. The inductor lacks its magnetizing ability as an outcome of the same charging and discharge issues that affect the capacitor. Table 3 shows that the current via the switch and inductor reach an extremely significant level, which will undoubtedly cause the circuit to fail.

As the amount of time rises, we may see that the voltage flowing through the inductor climbs linearly to an extremely high level. Comparably, in the event of a switch short circuit malfunction, the gadget sustains significant harm as the current flowing through the switch's contacts rises linearly with time. The boost converter's ability to increase the voltage at the output is likewise stopped by a short circuit defect; instead, the input voltage is sent to the output without any switching occurring. The power source is still being charged, but at a lower voltage, which is not what is desired for efficient battery charging.

Table. 2. summit quantities of various parameters in Switch Open Circuit fault for Boost Converter

Inductor		Switch		Capacitor
Voltage(V)	Current(A)	Voltage(V)	Current(A)	Voltage(V)
0	3.21	8.9	0	8.19
Diode		Battery		
Voltage(V)	Current(A)	Voltage(V)	Current(A)	SOC
0.79	3.21	8.19	3.16	Charging

Table. 3. summit quantities of various parameters in Switch Short Circuit error for Boost Converter

Inductor		Switch		Capacitor
Voltage(V)	Current(A)	Voltage(V)	Current(A)	Voltage(V)
0	>399	8.9	>399	8.19
Diode		Battery		
Voltage(V)	Current(A)	Voltage(V)	Current(A)	SOC
0.79	3.49	8.19	3.49	Charging

Defect in Resistor Open Circuits

Capacitor open circuitry is a different sort of malfunction. Since it doesn't raise the circuit's voltage or current, this defect doesn't harm any devices. However, it cuts off the load's availability.

The distribution of voltage and current in the circuit. The output voltage remains unchanged long following a malfunction. Therefore, the efficiency of charging the power source is unaffected by the open circuit defect in the capacitor. The open circuit fault at the power source is the final potential defect. The device's whole supply is shut off from the other components if this scenario occurs. Thus, the output is going to be close to nil. As a result, the various faults that could arise in a boost converter circuit are examined, and their respective responses are recorded and contrasted. As we observe, there are times when defects cause the voltage and current to spike to extremely high levels, which puts stress on the circuitry and degrades production efficiency. Therefore, the purpose of a tolerant of faults boost converter is to prevent unneeded stress from being produced by various defects while maintaining the device's efficiency.

5. Conclusions

It is evident from the findings provided that short circuit and diode open circuit problems are among the most frequent and dangerous types of defects. The optimum solution for these issues is a fault tolerant DC to DC converter. Although there are several fault-tolerant converters on the market, they don't always work right away. When a controller is present in the circuit, it detects the defect and acts on the converter to lessen its impact. Although the additional switch, diode, and controller are more expensive, they provide the converter with greater safety and extend its lifespan while improving performance. Therefore, fault analysis assists in developing a fault-tolerant DC-DC converter by indicating the severity of different errors. To gain more insight into the converter's operation during various failure scenarios, additional temperature measurement may be conducted.

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Conflicts of Interest: Declare conflicts of interest or state “The authors declare no conflict of interest.”

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