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Automatic Switch Fault Diagnosis And Rectification In Boost Converter

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***Abstract*—In this paper, a fault tolerant operation of a single switch dc-dc converter under switch failure is proposed. The fault tolerant operation of a power system can be performed inthree steps: fault detection, identification and remedial action. In case of a switch failure, it is essential to identify the fault and rectify it as soon as possible to avoid its propagationthrough the system. This proposed paper can distinguish between open circuit and shortcircuit fault using a fault detection algorithm. The inductor current is taken as thereference. By comparing the PWM signal and the inductor current, the fault is detected.An auxiliary switch is needed for converter reconfiguration in post fault operation.**

***Index Terms*—About four key words or phrases in alphabetical order, separated by commas.**

I. Introduction

The dc-dc converters are widely used in many industrial applications such as aerospace,ships, electric vehicles and renewable energy power systems. From the application point of view reliability is one of the important factor that has to be considered nowadays. Reliability is the ability of an item toperform the required function under stated conditions for a certain period of time, whichis often measured by probability of survival and failure rate. Therefore reliability in theseembedded systems and in safety critical applications has been improved with the integrationof fault diagnosis and fault tolerant architectures. Fault tolerance in a power converter needsthree steps: fault detection, fault identification and remedial actions. The first two steps are used to find the location and nature of fault. In remedial actions, first the faulty device isisolated if needed and then reconfigure the converter to guarantee the service continuity. In most dc-dc converters, the critical elements are aluminum electrolytic capacitors andsemiconductors. About 60% of the converter faults are due to electrolytic capacitors. Semiconverter faults and soldering joints failure contributes about 34%. The inductive elements constitute about 8% of the total converter faults. Diodes constitute about 5% of the total converter faults.

Working outside the safe operating area leads power semiconductors to damage. Themain failure causes are a)fault current either over current; b)short circuit current or earthfault current; c)over voltage; d)over temperature; e)cosmic radiations. Other problems mayarise because of the driver of the power semiconductors: malfunctioning of the driver board,auxiliary power supply failure or large dv/dt disturbances. As a consequences, five main types of faults can be identified: 1)single switch short circuit 2)phase leg short circuit 3)single switchopen circuit 4)single phase open circuit 5)intermittent gate mis-firing. Several diagnostic methods are used to find out the faults. Once the fault is detected and isolated or onlinerepair is implemented , the system can continue to operate safely and fault tolerant operationis implemented.

In a dc-dc converter system, open circuit fault and short circuit faults are the most common. This paper deals with the open and short circuit fault in a single switch converter system. Here the fault is first detected through a fault detection algorithm. After thedetection, the faulty switch is replaced by another auxiliary switch and the operation iscontinued.

Most of the power electronic systems are dealing with buck , boost or derived formsof these converters. Reliability is one of the main factor which has to be dealt with. In many mission profile applications like aerospace, military, more electric aircraft's, railway traction's, automotive, data center and medical electronics the continuity of operation is very important.

Inorder to make a system more reliable, the continuity of operation of circuit is very much important. That is, even when a fault occurs in system, through some remedial action the continuity of output must be ensured. Nowadays, many fault detection algorithm are effectively used to detect the fault in many converters. Many fault rectification ways are alsoused to rectify the fault, which may vary from converters to converters.

But the main disadvantage of all these present systems is that, for fault detection, many additional sensors and auxiliary parts like tertiary winding (full bridge converters) are used. And above all these, for fault rectification, many additional switches, legs(for H-bridge) are used. These all will increase the losses, size, cost and complexity of the system. Thereby theperformance of system is reduced.

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The objective of this project is to:
1) Effectively find out the fault with reduced number of sensors
2) To rectify the fault within minimum time and with reduced number of switches
3) To ensure the continuous operation of the circuit even during faulty condition.

I. PROPOSED TOPOLOGY

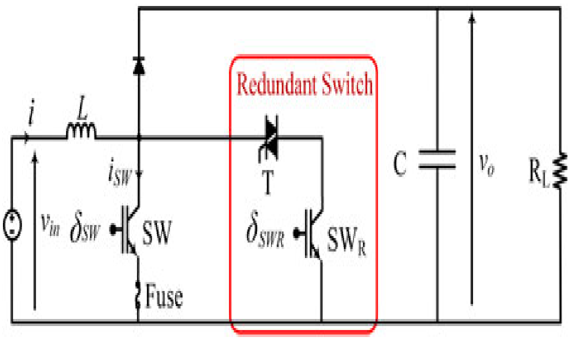

Fig. 1.Boost converter incorporating fault tolerant operation

The above figure shows the fault tolerant circuit of a boost converter[1]. The circuit consists of two switches, one main switch and another one an auxiliary switch. The auxiliary switch in is connected in parallel with the main switch through a TRIAC. A fuse unit is incorporated in the circuit to isolate the main switch during the faulty condition from the circuit. When a fault occurs in the circuit, the operation is shifted from the main switch to the auxiliary switch. There by the operation is continued.

II. SIMULATION DIAGRAM

The Fig.2 shows the open circuit simulation diagram of an open loop boost converter. The fault is created using a fault generator which is basically a pulse generator. Fault is created in an assumption that, either the open circuit or short circuit fault is produced at a time. An auxiliary switch is connected in parallel with the main switch which helps in fault rectification during the faulty condition.

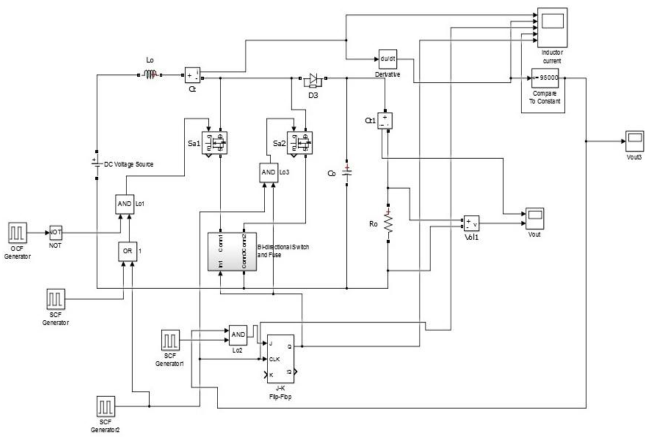

Fig. 2.Boost Converter Open Circuit

MODIFICATION:

The closed loop diagram of the proposed converter is shown in Fig.3. When a circuit is operated in the closed loop condition, the output voltage is regulated, the ripple is reduced, output voltage can be achieved to the required value.

Fig 4 shows the subsystem of the system. It contains a main switch and auxiliary switch, connected in parallel with each other.

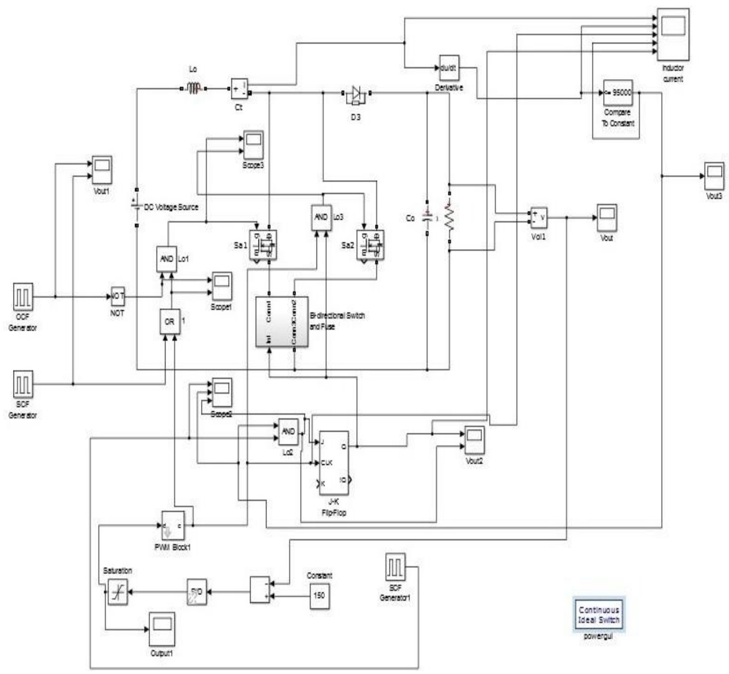

Fig. 3.Boost Converter Closed Circuit

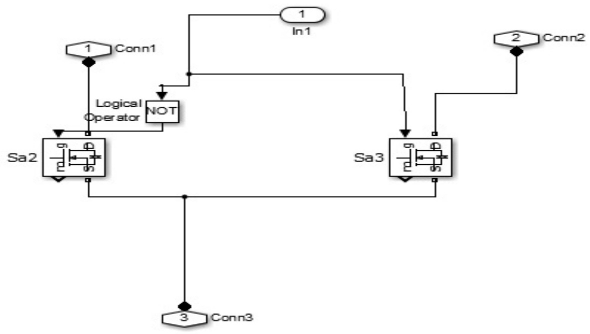

Fig. 4.Boost Converter-Sub System

III. SIMULATION RESULTS

Simulation results will discuss how the fault tolerant circuit works in open circuit fault condition and short circuit fault condition. First the open circuit fault condition is discussed. In both open and short circuit condition, it mainly involves three steps fault detection, fault identification and fault rectification.

OPEN CIRCUIT CONDITION:

Fault is generated using a pulse generator which is shown in the Fig 5. To createan Open Circuit Fault, the gate signal is made to zero. So that, the switch is in zero stateor non conducting state.

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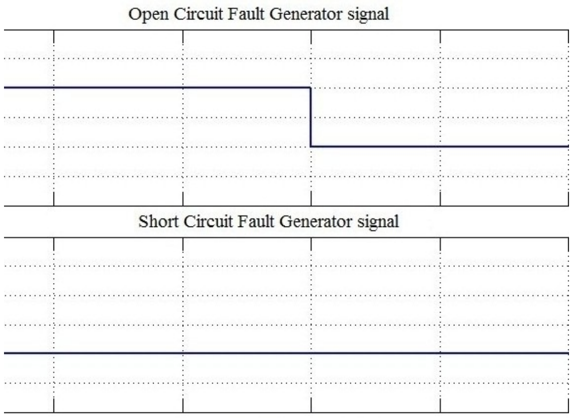

Fig. 5.Open Circuit Fault Generation

Fig 6 shows the condition of circuit during open circuit condition. Inorder tocreate an open circuit condition we are not giving gate signals to the switch. So it act as anopen circuit condition. In this state, the inductor current goes on decreasing, which is shownin the waveform. The inductor current is given to the di/dtblock. When the di/dtbecomes <= 96000, the output from block becomes high. This signal is given to the AND gate where itget compared with another signal, to avoid the fault detection during the initial stage of theinductor charging. The output from the AND gate is given as the input to the J-K flip-flop.The PWM signal is given as the clock to the J-K flipflop. During the faulty condition, boththe J and clock becomes high. So the output Q becomes high, and thus the fault is detected,which is shown in the waveform.

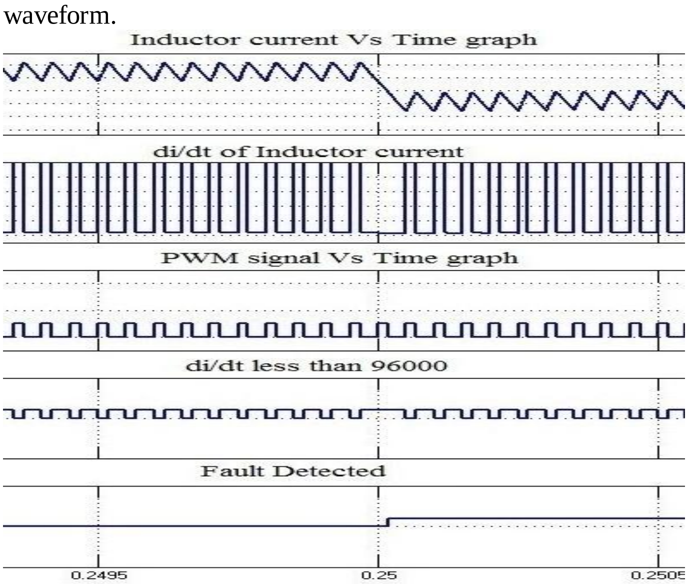

Fig. 6.Open Circuit Fault Detection

Fig 7 shows the rectification of fault in the converter. Open circuit fault is generated at time t=0.25 sec. The Fault Detection Algorithm detects the fault. After faultdetection, the faulty switch is isolated from the circuit by blocking the control signals to thefaulty switch. The fault is rectified through an auxiliary switch connected in parallel withthe main switch. The operation is continued by giving gate signals to the auxiliary switch.

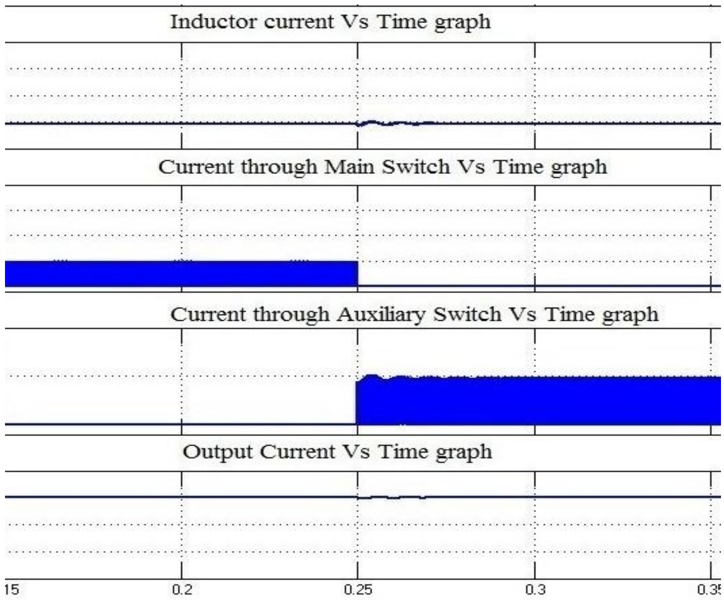

Fig. 7.Open Circuit Fault Rectification

SHORT CIRCUIT CONDITION:

Fig 8 shows the generation of Short Circuit Fault. Inorder to create a Short CircuitFault, a continuous high signal is given to the switch. So, the switch will always be in theconducting state. This high state of the switch represents the short circuit condition of theswitch.

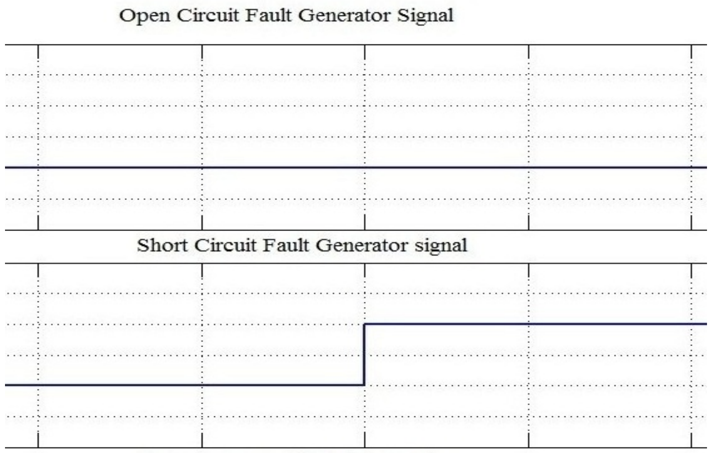

Fig. 8.Short Circuit Fault Generation

Fig 9 shows the condition of circuit during short circuit condition. Inorder tocreate a short circuit condition we are giving a high gate signals to the switch. So it act asan short circuit condition. In this state, the inductor current goes on increasing and later theinductor current become constant, which is shown in the waveform. The inductor current isgiven to the di/dtblock. When the di/dt becomes <=96000, the output from block becomes high.This signal is given to the AND gate where it get compared with another signal, to avoid thefault detection during the initial stage of the inductor charging. The output from the ANDgate is given as the input to the J-K flipflop The PWM signal is given as the clock to theJ-Kflipflop. During the faulty condition, both the J and clock becomes high. So the outputQ becomes high, and thus the fault is detected, which is shown in the waveform.

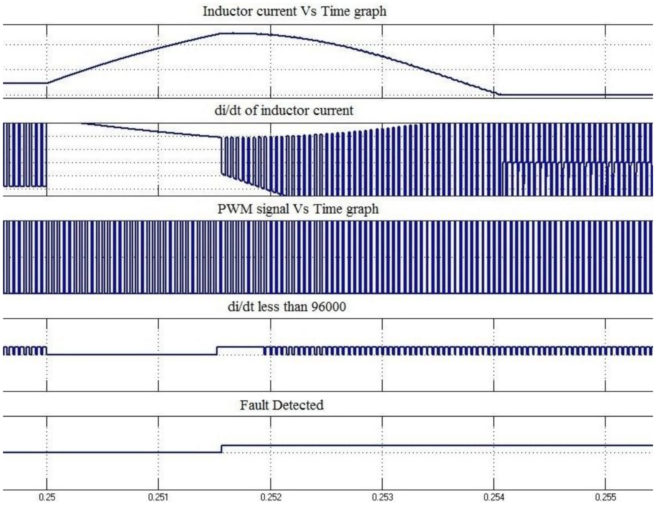

Fig. 9.Short Circuit Fault Detection

The short circuit fault rectification of the boost converter is shown in the Figure 10.The fault is detected using Fault Detection Algorithm. After the fault detection, the faultyswitch is isolated from the circuit and operation is continued using an auxiliary switch. Attime t=0.25, there is a disturbance in the output current and voltage. These disturbance isdue to the change in operation from the main switch to the auxiliary switch.

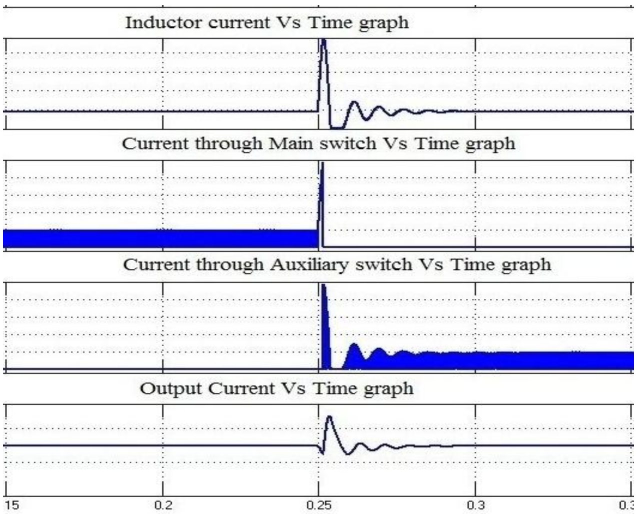

Fig. 10.Short Circuit Fault Rectification

IV. CONCLUSION

This paper has proposed a FT operation of a single switch dc-dc converter for open and short circuit switch failures. The proposed FDA can identify and detect the type of fault very effectively. The inductor current and the PWM signal are the only parameters used to detect the fault. The simulation is also carried out. The open and short circuit faults are detected effectively. These faults are isolated and rectified as fast as possible. Operation iscontinued using an auxiliary switch connected in parallel with main switch.

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