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Simulation of Diagnosing and Protecting the Boost Converter Circuit from Open Circuit and Short Circuit Switch Fault

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Abstract— Diagnosing Fault in a DC-DC converter is important to prevent the damage of converter. The objective of the paper is diagnosing the fault occurred and preventing the damaging of the converter. This Paper deals with the simulation of open and short circuit switch fault analysis in the DC-DC Converter using MATLAB Simulink. The converter used here is Boost Converter which is also known as Step up Converter. The faults are created here by the external circuit and it is cleared using a closed loop control ant the corresponding waveforms are studied. The results of simulations are compared with theoretical results. A simulink model is developed and it is successfully used for fault diagnosis.

Keywords— Boost Converter, (SCF) Short Circuit Fault, (OCF) Open Circuit Fault, Circuit Breaker.

I. INTRODUCTION

DC-DC converter is the electronic device, whereas used to convert DC voltage from one level to DC voltage of another level. For about few days the DC-DC converters are highly used in all types of applications such as electric vehicles, drives, renewable energy power systems etc. Therefore it should be concentrated to have highly reliable DC-DC converter. The two important elements in DC-DC converters are semiconductors and aluminium electrolytic capacitor. From the survey of Literature it is said that more than 55% of mal-working occur in converter is due to electrolytic capacitor and 32% of mal-working in converters are due to semiconductor switches. Therefore the DC- DC converter should be with a fault tolerant capability, so that the working of the system is not disturbed.

The fault tolerant system has to perform three operations. They are fault detection, fault identification and remedial actions. In this paper fault identification which is otherwise called fault diagnosis is performed in Boost Converter [4] converter configuration. In literature several papers have reported the fault detection for power electronic converter. The faster diagnosis of switch fault in the converter is in [1]. The faults in the converter due to aluminium electrolytic capacitor and semiconductor devices are in [2]. The control of positive output elementary super lift LUO converter by PI is in [3]. The detection of fault in multilevel converter is in [5].

The open circuit fault detection in matrix converter is reported in [6][7]. The open circuit fault in the converter in Induction motor drives is reported in [8][14]. The diagnosis of fault by using FPGA is reported [9][15]. In [11] kalman filter is employed in ordinary DC-DC boost converter. In [10] fault detection was done in grid connected photovoltaic system. The open circuit fault diagnosis in a converter is reported in [12]

In this paper the switch fault in the DC-DC Boost converter is diagnosed during the operation and faulty section is isolated in boost converter. The circuit operation and its analysis of Boost converter is presented in section II. The simulation of Boost Converter with faults and without faults is presented in section III. The conclusion and future scope to this paper is presented in section IV.

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II. **Circuit operation**

Boost Converter circuit is shown in Fig.1, which perform Step Up operation. The Boost Converters is preferred due to its high voltage gain, less ripple content, high power density.

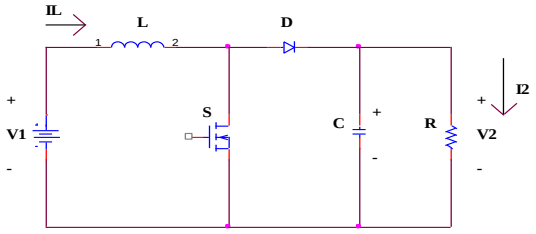

Fig.1 Circuit Diagram of Boost Converter

The Boost Converter or step up converter circuit consists of Inductor L, a semiconductor switch S, Diode D, capacitor C and the resistive load R. The input given to the Converter circuit is V1 and the output taken from the Converter circuit is V2.

A. Mode 1

The circuit diagram of Mode 1 operation in Boost Converter circuit is shown in Fig.2. In this mode the switch is closed so that it starts conducting. The diode D becomes non conducting (i.e) the semiconductor Switch is forward biased and the diode D is reverse biased. In this mode input is connected to the inductor and to the Switch S. The Capacitor C is parallel with the load resistor. The output voltage V2 will be the the voltage in the capacitor VC.

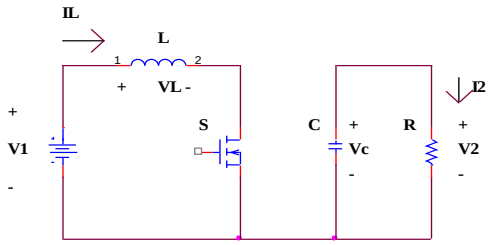

Fig.2 Circuit Diagram of Boost Converter during Mode 1

B. Mode 2

The circuit diagram of Mode 2 operation in Boost Converter circuit is shown in Fig.3. In this mode the switch is opened so that it becomes non conducting. The diode D becomes conducting (i.e) the semiconductor Switch is Reverse biased and the diode D is forward biased.

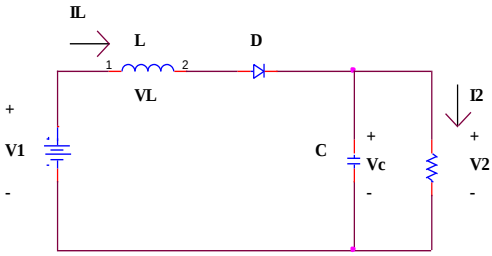

Fig.3 Circuit Diagram of Boost Converter

Assuming the inductor current increases linearly from I_1 to I_2 in timet_1,

$V_s = L\frac{I_2 - I_1}{t_1} = L\frac{\Delta I}{t_1}$

$t_1 = \frac{\Delta IL}{V_S}$

Now the inductor current decreases linearly from I_2 to I_1 in time t_2

$V_s - V_a = -L\frac{\Delta I}{t_2}$

$t_2 = \frac{\Delta IL}{V_a - V_s}$

Where $\Delta I = I_2 - I_1$ is the peak to peak ripple current of inductor L.

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$\Delta I = \frac{V_S t_1}{L} = \frac{(V_a - V_S)t_2}{L}$

Substituting $t_1 = KT$ and $t_2 = (1-K)T$ yields the average output voltage,

$V_a = V_S \frac{T}{t_2} = \frac{V_S}{1-K}$

Which gives (1-K) = $\frac{V_S}{V_a}$

Substituting $k = \frac{t_1}{T} = t_1 f$ yields

$t_1 = \frac{V_a - V_S}{V_a f}$

Assuming a lossless circuit,

$$V_S I_S = V_a I_a = V_S I_a/(1-K)$$

and the average input current in

$I_S = \frac{I_a}{1-K}$

The switching period T can be found from

$$T = \frac{1}{f} = t_1 + t_2 = \frac{\Delta I L}{V_S} + \frac{\Delta I L}{V_a - V_S} = \frac{\Delta I L V_S}{V_S(V_a - V_S)}$$

And this gives the peak to peak ripple current

$$\Delta I = \frac{V_S(V_a - V_S)}{f L V_a}$$

$\Delta I = \frac{V_S K}{f L}$

When the transistor is on, the capacitor supplies the load current for$t = t_1$. The average capacitor current during time t_1 is $I_C = I_a$ and the peak to peak ripple voltage of the capacitor is,

$\Delta V_C = v_c - v_c(t=0) = \frac{1}{C}\int_0^{t_1} I_C dt = \frac{1}{C}\int_0^{t_1} I_a = \frac{I_a t_1}{C}$

Substituting $t_1 = (V_a - V_S)/(V_a f)$

$$\Delta V_C = \frac{I_a k}{f C}$$

If I_L is the average inductor current, the inductor ripple current

$$\Delta I = 2I_L$$

$\frac{kV_S}{fL} = 2I_L = 2I_a = \frac{2V_S}{(1-k)R}$

Which gives the critical value of inductor L_C as

$L_C = L = \frac{k(1-k)R}{2f}$

If V_C is the average capacitor voltage, the capacitor ripple voltage $\Delta V_C = 2V_a$.

Using $\frac{I_a k}{Cf} = 2V_a = 2I_a R$

Which gives the critical value of the capacitor C_C as

$C_C = C = \frac{k}{2fR}$

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III. **Simulation**

The Boost Converter is simulated by the simulink of mat lab and the simulation parameter for the converter is shown in the below table 1.

TABLE I. SIMULATION PARAMETERS

Name Of The Component	**Symbol**	**Values**
Input Voltage	V1	14 V
Output Voltage	V2	42 V
Output Current	I2	8.3 amps
Inductance	L	11mH
Capacitance	C	1000mF
Resistance	R	5 ohms
Duty Cycle	D	0.6

The below circuit is the simulation Circuit diagram of the Boost converter and it is shown in Fig.4.

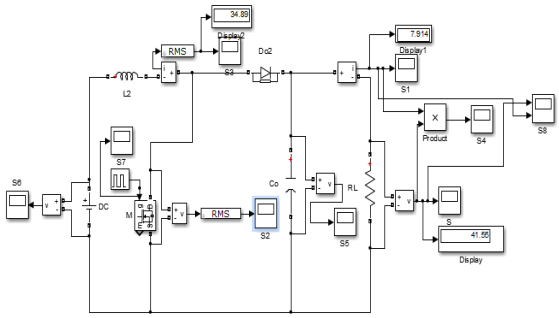

Fig.4 Simulation Circuit of Boost Converter

The DC input voltage to the Boost Converter is 14V and it is shown in Fig.5. The inductor current of Boost Converter is shown in Fig.6.and it is 34 amps. The output voltage is shown in Fig.7 and it is 41.5 V. The Output Current of Boost Converter is shown in fig.8 and it is 8.3amps.

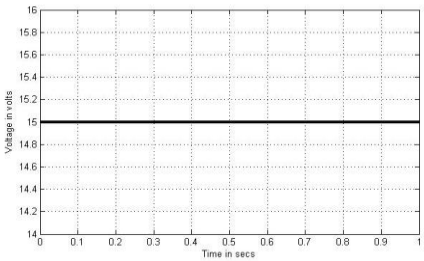

Fig.5 Input Voltage of the Boost Converter

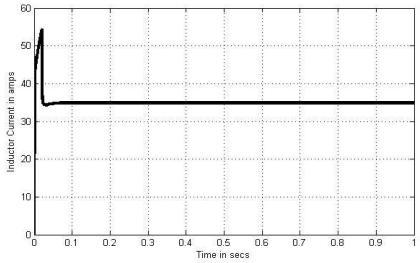

Fig.6 Inductor Current of Boost Converter

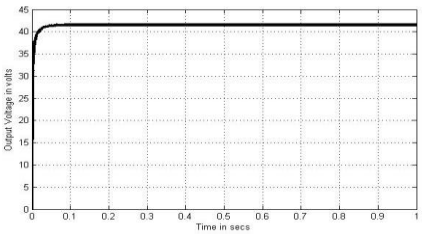

Fig.7 Output Voltage of Boost Converter

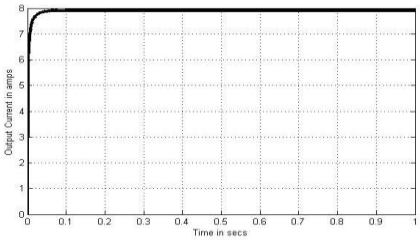

Fig.8 Output Current of Boost Converter

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Now the Boost Converter with Short Circuit fault is simulated using the blocks of simulink. The circuit diagram for the Boost Converter with short circuit switch fault is shown in Fig.9

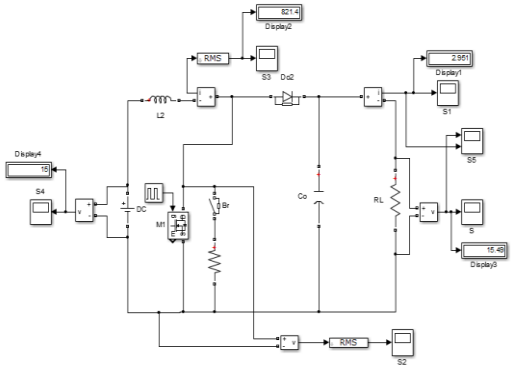

Fig.9 Boost Converter with Short Circuit Fault

Short Circuit Fault in the device is created by connecting the low value of resistance in parallel with switch through a circuit breaker. The value of resistance connected is low so the current starts to pass through the resistance because the value of resistance is low, when the circuit breaker is closed. So there occurs a shorting of switch. Now due shorting the inductor current increases enormously high to above 800 Amps from its normal value. When there is a increase in inductor current from its normal value it is said to be the occurrence of short circuit fault and it is shown in Fig.10. The output voltage of the Boost Converter decreases to 16V and it is shown in Fig.11. The output current decreases to 2.9 amps and it is shown in Fig.12.

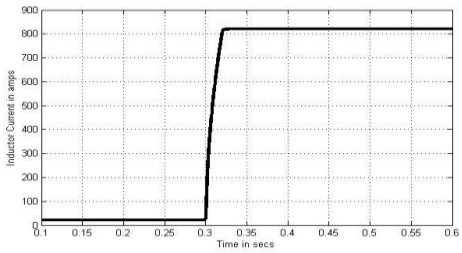

Fig.10 Inductor Current during Short Circuit Fault

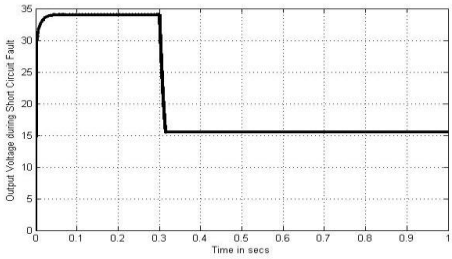

Fig.11 Output Voltage during Short Circuit Fault

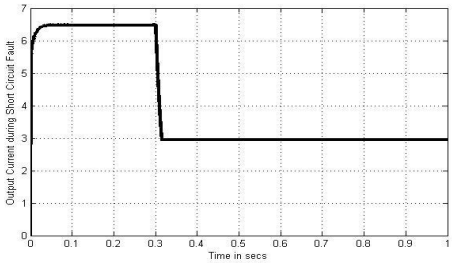

Fig.12 Output Current during Short Circuit Fault

The circuit for clearing the short circuit fault is shown in Fig.13. This Circuit consists of one additional circuit breaker in it. Whenever there is a occurrence of short circuit switch fault, the breaker disconnects source and the converter circuit, and thus the converter is protected from damage due to high current. The input voltage is 14V which is shown in Fig.5. The inductor current decreases to 0 amps which is shown in Fig.14. The output voltage also decreases because of the opening of the circuit breaker to 0V which is shown in Fig.15. The output current is 0.007 amps which is shown in Fig.16. The switching signal to the circuit breaker is shown in Fig.17. The breaker signal will be "1" if there is no fault in the converter. But if there is a occurrence of fault the signal to the breaker is "0".

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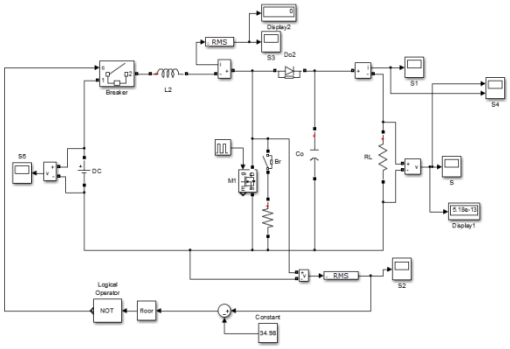

Fig.13 Short Circuit Fault Clearance Circuit

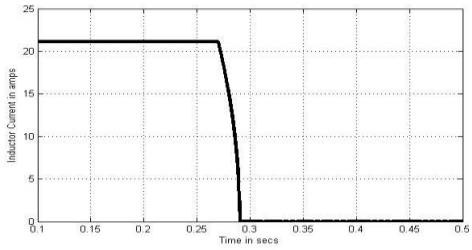

Fig.14 Inductor Current in Short Circuit Fault Clearance Circuit

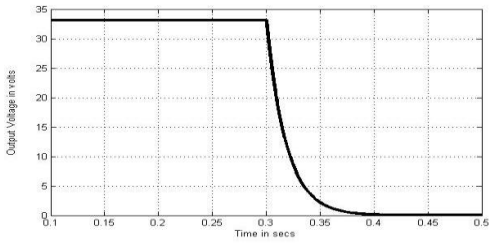

Fig.15 Output Voltage Of Open Circuit Fault Clearance Circuit

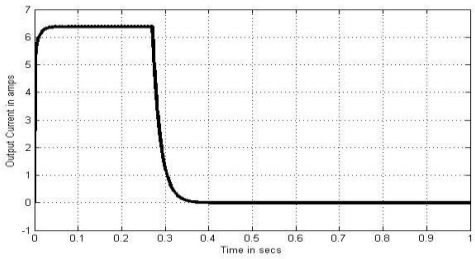

Fig.16 Output Current of Short Circuit Fault Clearing Circuit

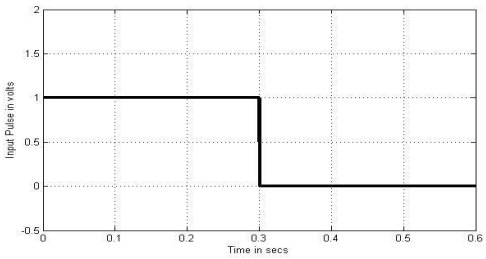

Fig.17 Input Pulses to the Circuit Breaker

Now the Boost converter with open Circuit fault is simulated by using the blocks of simulink. The circuit diagram with open circuit switch fault is shown in Fig.18.

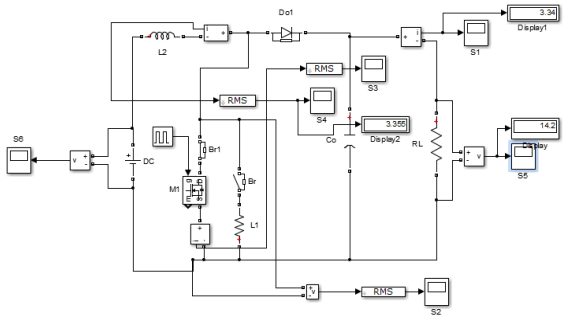

Fig.18 Boost Converter with Open Circuit Fault

The Open Circuit Fault in the Boost Converter circuit is created by connecting the high resistance in parallel with switch through circuit breaker. And also to make open circuit fault the switch is connected in series with the circuit breaker. The value of resistance connected is high so that the current is made to flow in resistor by disconnecting the switch using a breaker so the open circuit fault occur in the converter circuit. The input DC Voltage is 14V which is shown in fig.5. The decreasing of inductor current is shown in Fig.19. The output voltage is 14 V which is shown in Fig.20. The output current also decreases to 2.8 amps and it is shown in Fig.21

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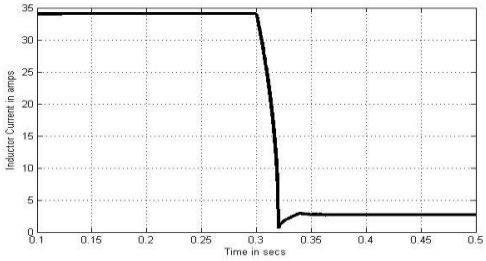

Fig.19 Inductor Current Of Boost Converter with open Circuit Fault

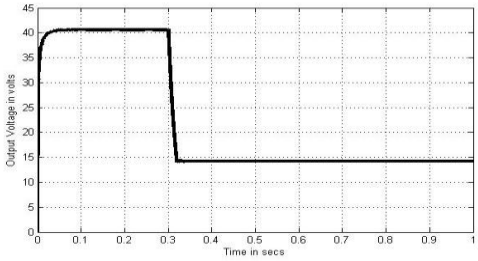

Fig.20 Output Voltage of Boost Converter with open circuit fault

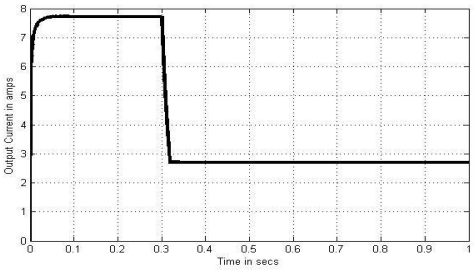

Fig.21 Output Current of the converter during open circuit fault

The circuit for clearance of open circuit fault is shown in Fig.22. The input voltage is 14 V shown in Fig.5. The inductor current gets reduced 0 amps and it is shown in Fig.23. The output voltage is 9.8 V and it is shown in Fig.24. The output current is 0.41 amps shown in Fig.25. The input signal to the breaker is show in Fig.26. The breaker signal will be "1" if there is no fault in the converter. But if there is fault the signal to the breaker is "0".

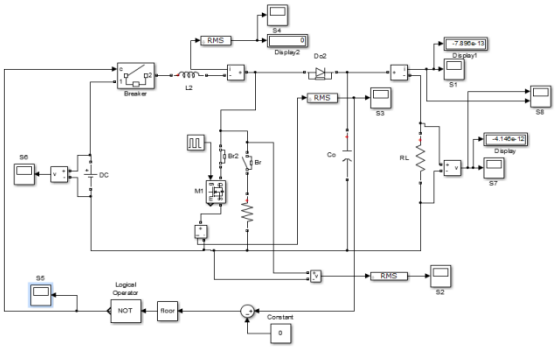

Fig.22 Open Circuit Fault Clearance Circuit

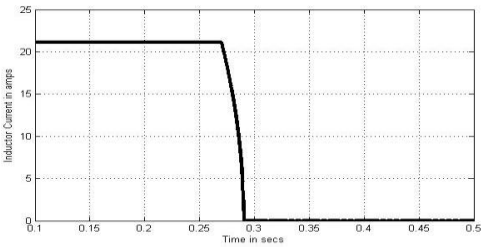

Fig.23 Inductor Current in Short Circuit Fault Clearance Circuit

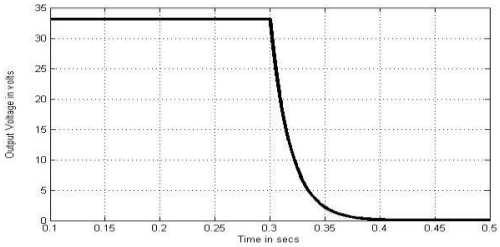

Fig.24 Output Voltage of Open Circuit Fault Clearance Circuit

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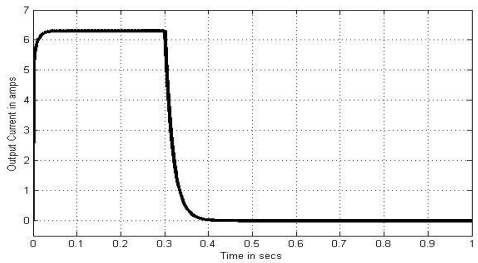

Fig.25 Output Current of Open Circuit Fault Clearance Circuit

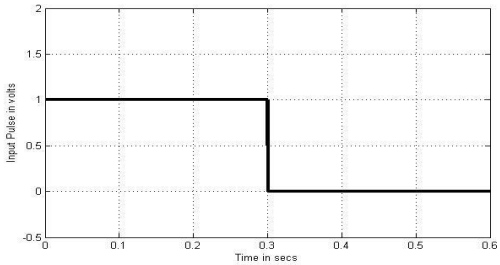

Fig. 26

CONCLUSIONS

In this paper, Short circuit and open circuit Switch faults are created by the blocks of simulink, analyzed and simulated successfully. The blocks of simulinks are simulated and the waveforms for short circuit and the open circuit switch faults are presented. The indication of increasing current in the inductor represents the short circuit fault. From the waveforms the indication of high current in the inductor represents short circuit fault of the switch and the indication of Zero or low current represents the open circuit switch faults. The present work deals with crisp logic controlled simulation study.

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