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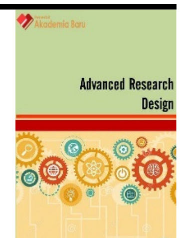

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Simulation of EMP Generator using MATLAB

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ABSTRACT

Electromagnetic pulse (EMP) is a sudden burst of wide-band, high-intensity electromagnetic radiation. EMP also called as a transient electromagnetic disturbance, a short burst of electromagnetic energy. Effect of EMP to automobile is classify as medium threats to vehicle attacks where EMP aims at damaging electronic devices such as on board sensors and processors, CPU which found in almost all models from 1990's and forward. This paper presents a MATLAB simulation of EMP generator by means of Switch Mode Power Supply, thus the electrical shielding can be studied further. Theoretically, EMP generator is developed by implementing energy storage circuit and discharge control circuit. Sending a rapidly changing electrical current through a loop will create an electromagnetic field in the form of a pulse. The results show an increase in pulse voltage from 12 VDC to 758 VDC with a current of 1500 A. A MATLAB model on the coverage area affected by EMP pulse will be developed in the next phase of the research.

1. Introduction

Electromagnetic pulse (EMP) is a sudden burst of wide-band, high-intensity electromagnetic radiation. EMP also called as a transient electromagnetic disturbance, a short burst of electromagnetic energy. EMP can cause large voltage and current transients that result in anomalous response in electronic system. These response are broadly divided into two mode of EMP damage; physical damage and upset [1-3, 7].

Effect of EMP to automobile is classify as medium threats to vehicle attacks where EMP aims at damaging electronic devices such as on board sensors and processors, CPU which found in almost all models from 1990's and forward [4]. The rest of the part may very well unaffected, however computer ignition chips and microcircuits that control many engine functions may be rendered inoperable by the pulse. The response of the vehicles towards EMP threats will depend on the

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composition and configuration of the electronic system as well as the type and level of the electrical shielding [5-8].

Most of EMP research focused on the electromagnetic radiation pulse source, cone angle and transition section and the physical parameter of the design, and some results [9-14]. This paper presents a MATLAB simulation of EMP generator by means of Switch Mode Power Supply, thus the electrical shielding can be studied further. A MATLAB model on the coverage area affected by EMP pulse will be developed in the next phase of the research.

2. Simulation of EMP Generator

EMP generator is developed by implementing energy storage circuit and discharge control circuit. Sending a rapidly changing electrical current through a loop will create an electromagnetic field in the form of a pulse. EMP generator schematic is shown in Figure 1.

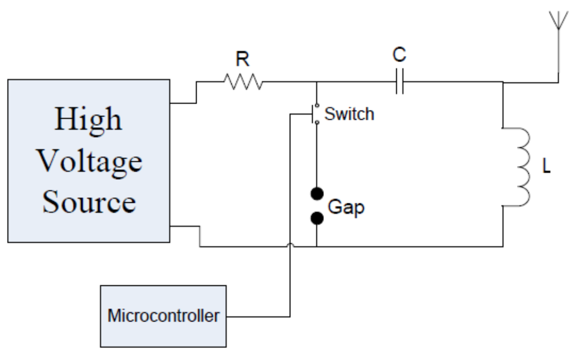

Fig. 1. Schematic of EMP

Multilevel boost converter is used to produce a high voltage source from a 12 Vdc battery source to 758 Vdc as shown in Figure 2 and the converter is also used to supply energy to the capacitive network by varying the duty cycle. The output voltage of the Multilevel Boost Converter can be derived by equation 1 [15-17], assuming in an ideal state. *D* is the duty cycle in MOSFET and *N* is a number of levels Multilevel Boost Converter.

$$V_{out} = N \times \frac{1}{1-D} V_{IN} \quad (1)$$

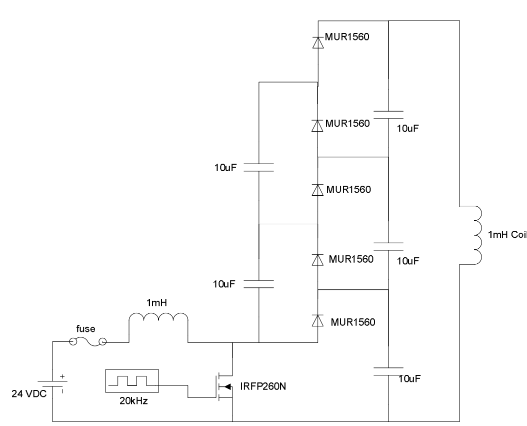

Fig. 2. Multilevel Boost Converter

Circuit RLC is used to create the electromagnetic field. The pulse of EMP must have fast rise time and burst duration to maximize the effect. EMP needs a capacitor with low inductance and low ESR (Equivalent Series Resistance) to make fast rise time current impulse[18][19]. Electromagnetic field waves produced is in a form of a sine wave with a damping factor depending on the RLC circuit which are overdamping, critical damping and underdamping [20] as shown in Figure 3.

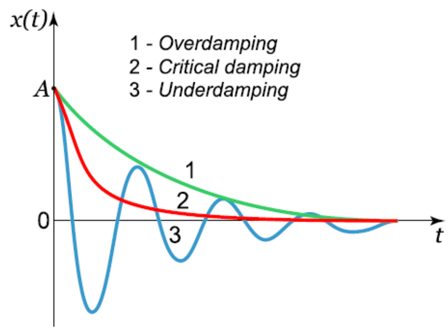

Fig. 3. Sine wave with damping factor

Damped oscillations can be written as:

$$\frac{d^2I}{dt^2} + \frac{R}{L}\frac{dI}{dt} + \frac{I}{LC} = 0 \quad (2)$$

$$\lambda^2 + \frac{R}{L}\lambda + \frac{I}{LC} = 0 \quad (3)$$

Equation 3 is calculated according to the following:

$$\lambda_{1,2} = \frac{\frac{-R}{L} \pm \sqrt{\frac{R^2}{L^2} - \frac{4}{LC}}}{2} \quad (4)$$

Where the value damping coefficient resonant frequency is in equation 5.

$$R^2 = \frac{4L}{C} \quad (5)$$

In the case, damping factor has 3 options:

1. Overdamping
   If $R^2 > \frac{4L}{C}$, so the waves do not show oscillation.
2. Critical Damping
   If $R^2 = \frac{4L}{C}$, so the waves response shows a narrow peak, but then it quickly decreases exponentially.
3. Underdamping
   If $R^2 < \frac{4L}{C}$, so the waves show oscillation.

The circuit uses critical damping from equation 5 to determine value of R, L and C. The internal resistance of the circuits is 0.3 Ω, the capacitance 1 μF, and inductor of 22.5 nH. The switch uses an IGBT with high voltage, high current and low internal resistance.

4. Result and Discussion

The simulation of EMP was performed in MATLAB. The charging voltage of the capacitor is 758 Vdc supplied by the multilevel boost converter. When switching off, the capacitor stores energy according to Q_{max} (see equation 6) for 0.2 seconds. When switch on, the capacitor discharges high current to RLC circuit and spark gap. The pulse wave from circuit RLC will produce the electromagnetic field.

$$Q_{max} = \left[1 - e^{-t/RC}\right] \tag{6}$$

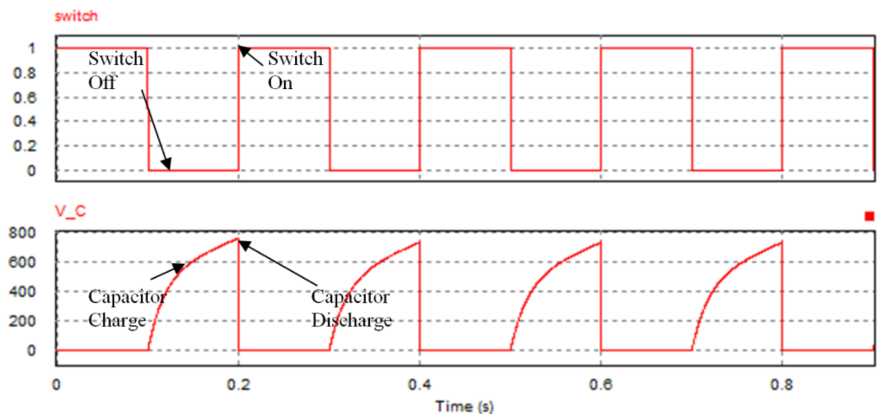

Fig. 4. The voltage waveform

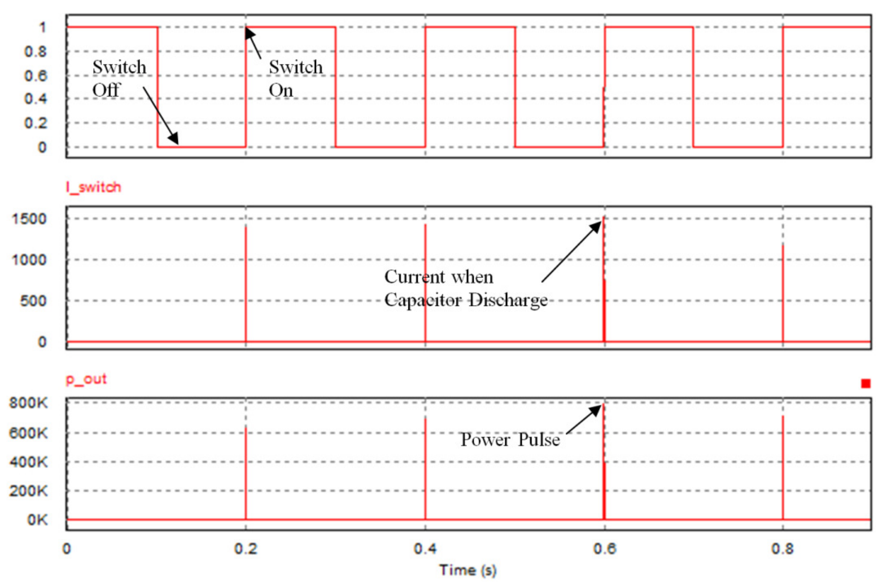

Fig. 5. The current and power pulse waveform when capacitor discharge

The current when the capacitor discharge is 1.5 kA and the maximum pulse power when capacitor discharge is 800 kW. The pulse period is around 1 µs and the energy stored in the capacitor is about 0.287 Joule at voltage 758 Vdc according to equation 7.

$$E = \frac{1}{2}CV^2 \tag{7}$$

Energy in the inductor when the capacitor discharge during 0.2 seconds is about 0.133 Joule, as listed in equation 8 and 9.

$$E = \int P.dt \tag{8}$$

$$E = \int_0^{Qmax} P_{max} e^{-\frac{R}{2L}t} \tag{9}$$

5. Conclusion

The simulation results of EMP generator show an increase in pulse voltage from 12 VDC to 758 VDC with a current of 1500 A. The energy when capacitor discharge is 0.133 Joule with the energy storage in capacitor is 0.287 Joule. A MATLAB model on the coverage area affected by EMP pulse will be developed in the next phase of the research.

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