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Effect of Passive Damping on the Performance of Buck Converter for Magnet Load

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***Abstract*: A DC to DC converter is a lossless dc transformer that supply regulated output voltage under varying load and input voltage condition and also the converter parameter values changes with time and physical quantity like temperature etc. This paper presents the design and simulation of an open loop buck converter for magnet load using Simulink and Sim Power System library of MATLAB.**

Keywords: **Buck Converter, Magnet Load, Simulink (MATLAB).**

I. INTRODUCTION

The ever expanding demand for smaller size, portable, and lighter weight with high performance DC-DC power converters for industrial, communications, residential, and aerospace applications is currently a topic of widespread interest [1]. Switched-mode DC-DC converters have become commonplace in such integrated circuits due to their ability to up/down the voltage of a battery coupled with high efficiency. The three essential configurations for this kind of power converters are buck, boost and buck–boost circuits, which provide low/high voltage and current ratings for loads at constant switching frequency [1]. The topology of DC-DC converters consists of linear (resistor, inductor and capacitor) and nonlinear (diode and dynamic switch) parts. A buck converter, as shown in Fig. 1, is one of the most widely recognized DC-DC converter. Magnet power supplies have some special characteristics than regular power supplies used for general purpose. These are used to feed electromagnets [2]-[6]. The strength and quality of the magnetic field produced by the electromagnet depends on the current passing through it. Hence magnet power supplies are current regulated. Fig. 1 is the basic circuit of buck converter [7]. When switch is ON, current flows from V_d through the coil L and charge the output capacitor C and passes through the resistor R and develop output voltage V_o. The current when passes through the coil L, stores the energy.

When switch is OFF, free-wheeling diode D turns ON and energy stored in L is then released to the output side. If the buck converter operates in Continuous Conduction Mode (CCM) [7], the relation between the input voltage (V_d), output voltage (V_o) is given as:

$$V_o = dV_d \quad (1)$$

Where,

$$d = \frac{T_{on}}{T_{on} + T_{off}} \quad (2)$$

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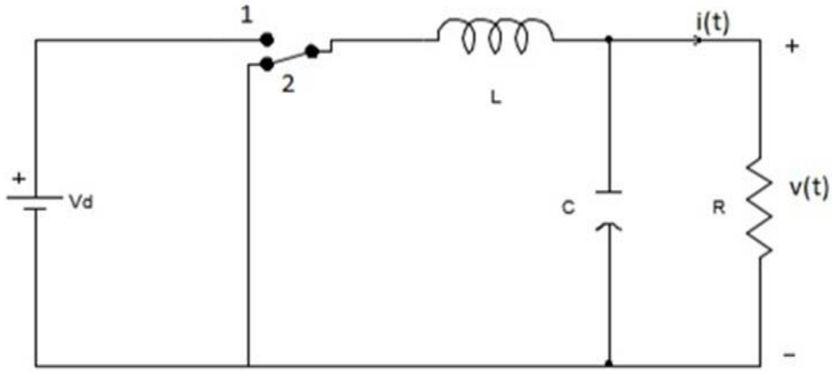

Figure 1: Basic DC-DC buck converter

To model a magnet load a resistance R_l in series with an inductor L_l can be used. Fig. 2 shows a DC-DC buck converter with a magnet load.

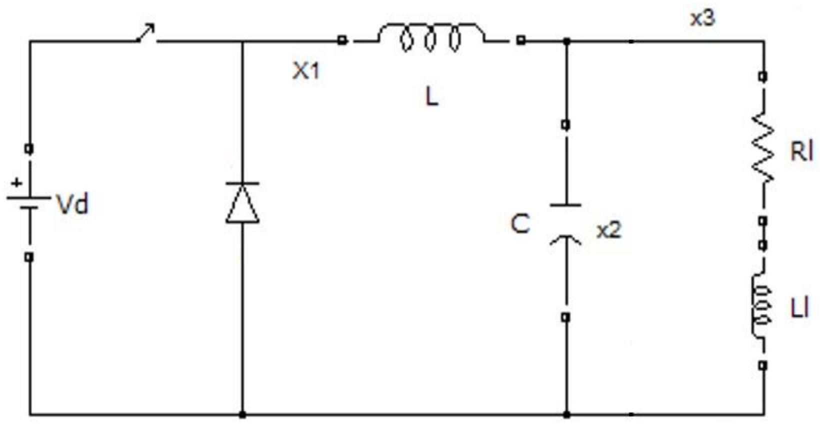

Figure 2: Buck converter with magnet load

Output voltage ripple of the DC-DC converter is minimized by proper selection of inductor and capacitor The filter inductor value and its peak current are determined on the basis of specified maximum inductor current ripple. The function of the output capacitor is to filter the inductor current ripple and produce a stable output voltage. In high magnet power supply the output current stability is most important, as the magnetic field produced by the magnet is dependent on the current flowing through it. These magnets play an important role in the particle accelerators as they keep the beam of particle in the design orbit. Therefore, these magnetic field should have very low ripple and thereby making the requirement of the stability very high. Usually the ripple in the output current of magnet power supplies for particle accelerators is of the order of hundreds of parts per million (ppm). Hence study of the ripples in the output current of the power supply plays an important role. In this paper the ripple in the output voltage and current is studied by simulating the buck converter for a magnet load using Simulink/MATLAB for two cases.

1. The underdamped LC filter.

2. Damped LC filter.

II. DAMPING OF BUCK CONVERTER WITH MAGNET LOAD

The buck converter for magnet power supply as shown in fig. 2 consists of an LC filter to reduce the switching ripples that might deteriorate the output stability. This LC filter might resonate at a certain frequency which might cause oscillations in the circuit. Hence it is important that this LC filter should be damped. The magnet load having a high value of inductance provide the necessary damping to the filter. But, it is a common practice to standardize the converter for different types of magnetic loads and therefore, there might come a case where the *LC* filter doesn't get the required damping and resonate. To overcome this problem passive damping elements are used to damp the *LC* filter [8]. Fig. 3 shows the buck converter for magnet load with passive damping through R_dC_d.

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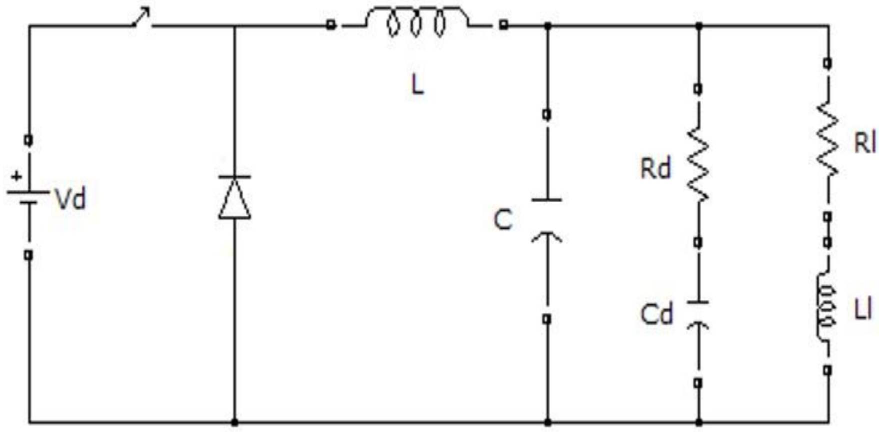

Figure 3: Buck converter with damped filter and magnet load

III. SIMULINK MODEL OF BUCK CONVERTER WITH MAGNET LOAD

Open loop Simulink model of buck converter with magnet load is shown in fig. 4. In fig. 4 the buck converter model the *LC* filter is underdamped [9]. The frequency response of the converter is shown in fig 5.

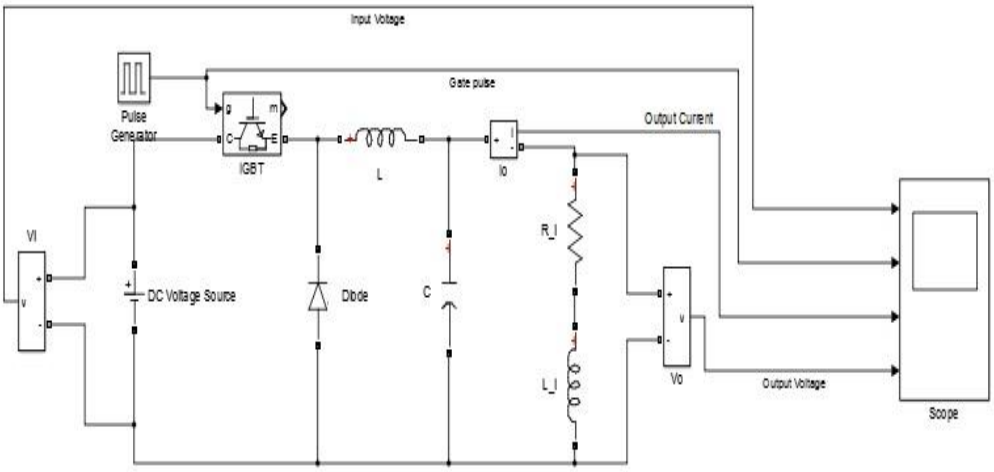

Figure 4: Simulink underdamped *LC* filter model of buck converter with magnet load

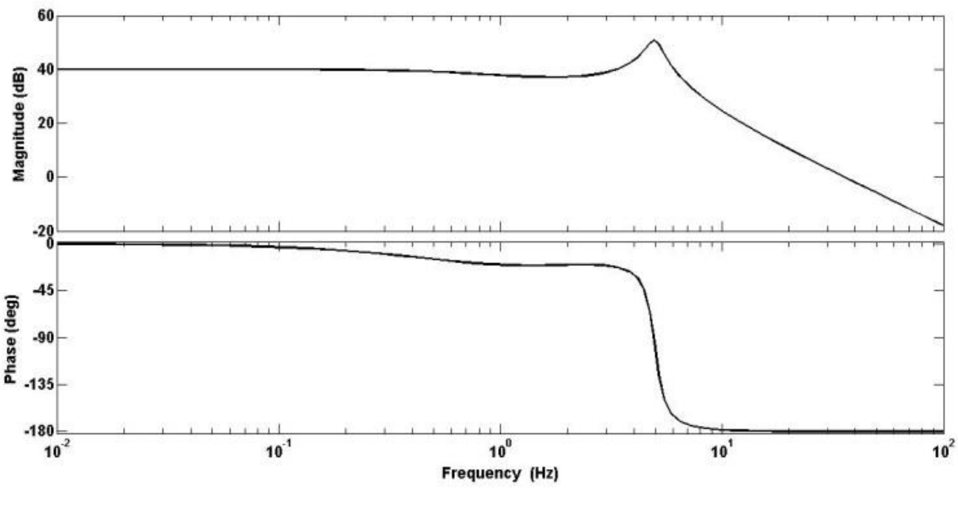

Figure 5: Frequency response of Buck converter with underdamped filter for magnet load

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As shown in fig. 5 the response of the buck convert with underdamped magnet load there is a resonant peak at the filter cut-off frequency. This peaking might amplify the noise entered in the system and deteriorate the output of the supply. Hence at a passive damping is provided using R_dC_d as shown in fig. 3. Fig. 6 shows the Simulink model of the buck converter with damped *LC* filter.

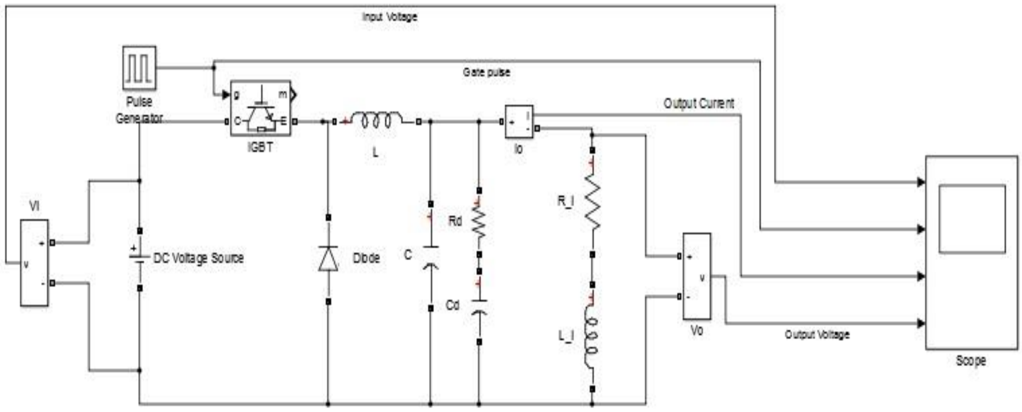

Figure 6: Simulink damped LC filter model of buck converter with magnet load

The frequency response of the damped converter shown in fig. 3 is shown in fig. 7

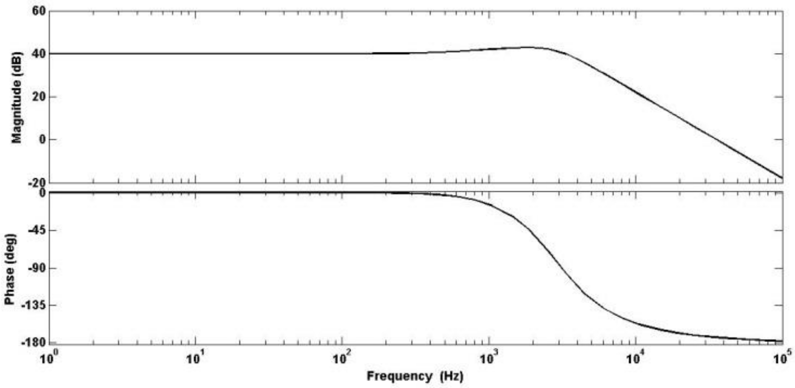

Figure 7: Frequency response of Buck converter with damped filter for magnet load

From fig. 7 it can be observed that the resonant peak of the *LC* filter has reduced significantly by the use of the passive damping elements R_dC_d.

IV. RESULTS AND DISCUSSIONS

In the previous section two different converter models were discussed. Each of the model is simulated under the same operating conditions with the parameters are listed in table 1.

Table 1: Parameters of converter for illustrative calculations

Parameters	Values
V_d	100 V
L	100 mH
C	20 mF
L_l	100 mH
R_l	1 Ω
R_d	2 Ω
C_d	100 mF
Duty Cycle	90 %

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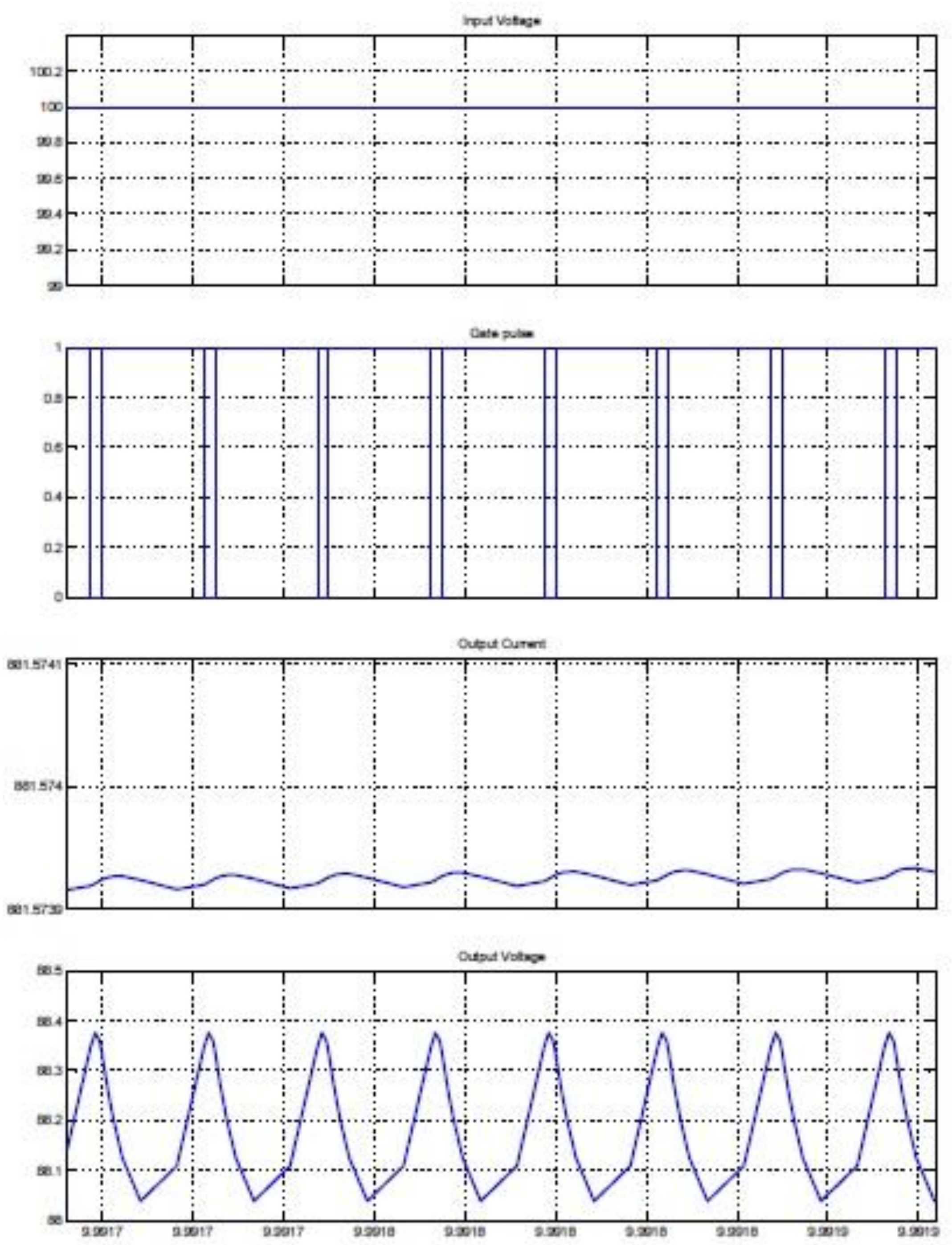
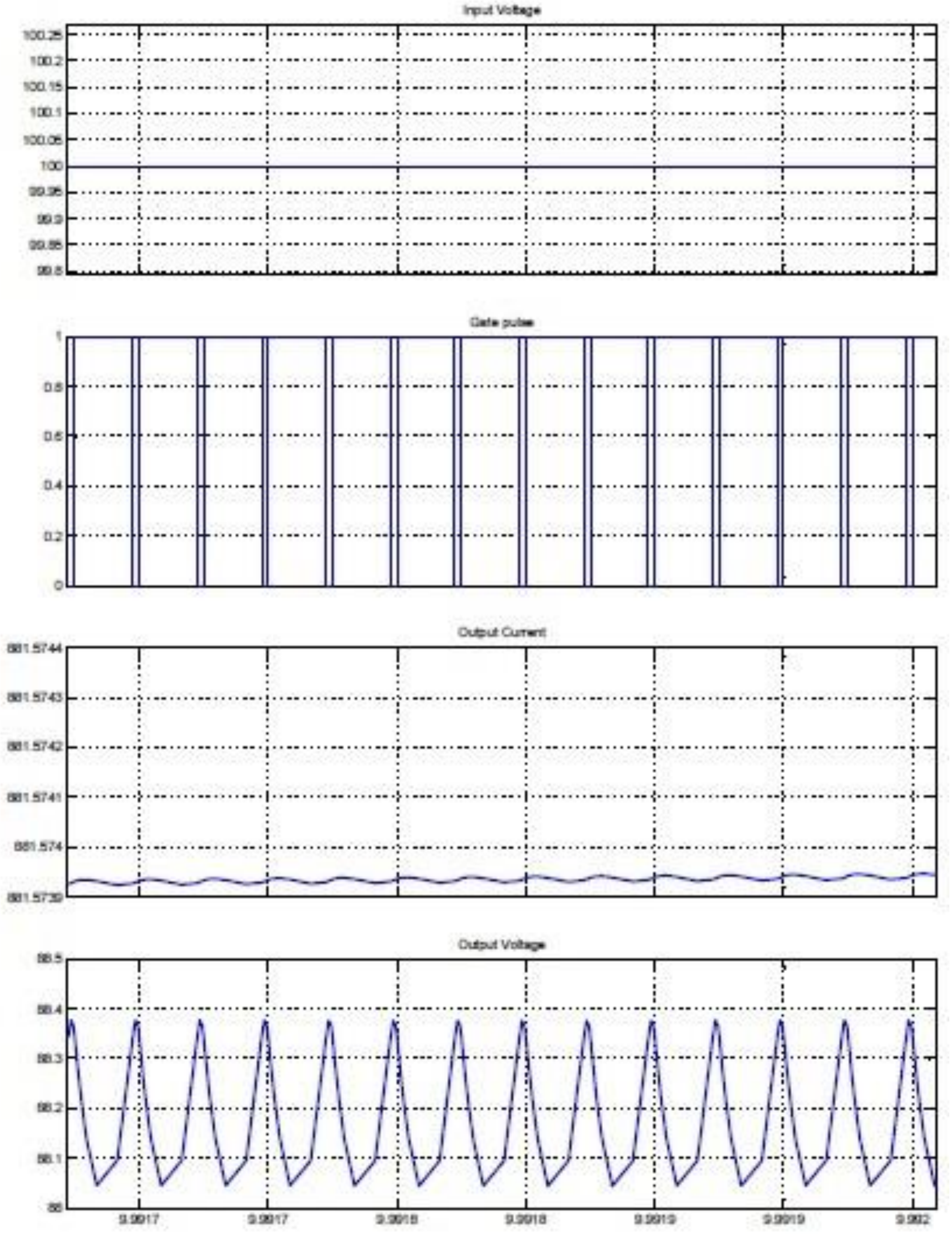
Following outputs were obtained from the Simulink models of both the converter circuit shown in fig. 4 and fig. 6.:

- Input voltage V_i
- Gate pulse (duty cycle)
- Output current I_o
- Output Voltage V_o

Fig. 8 (a) shows the output waveform of buck converter for magnet load with underdamped *LC* filter and (b) shows the output waveforms of buck converter for magnet load with damped *LC* filter.



(a)



(b)

Figure 8: Output wavefrom of conveter with magnet load for (a) underdamped filter and (b) damped filter

From fig. 8 (a) and (b) it can be observed that the ripple in the output current is reduced with the use of the passive damping with R_dC_d and also from fig.7 it can be observed that the resonant peak of the converter LC filter is reduced, which ensures that the high frequency noise introduced will not be amplified by the converter filter.

V. CONCLUSION

The buck converter model with magnet load has been simulated with and without the passive damping of the *LC* filter and it has been found that the converter circuit with a damped *LC* filter provides more stability to the system by damping the resonant peak of the *LC* filter at the filter cut-off frequency and also provides better ripple reduction in the output current.

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