Inductor Design Minimizing Power Loss for Boost Converter

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ABSTRACT

This paper proposes a method for designing the inductor to minimize power loss for boost converter. The proposed inductor design method uses genetic algorithm to find an optimal inductance and an optimal frequency which minimize the power loss at rated power. The validity of proposed inductor design method is verified by simulation and experiment.

1. Introduction

In boost topology the inductor is responsible for an important part of the volume and the loss of the converter. In particular, a higher inductance value of boost inductor results in lower electromagnetic interference (EMI) and higher efficiency at the expense of higher costs and size[1].

Unfortunately, the conventional inductor design procedure can lead to a non-optional design of inductor, since the inductor ripple current is selected arbitrarily. Usually the inductor ripple current is selected as 10~20% of inductor dc current, but sometimes another percentage will be better. So it can lead more converter loss and cost. As same as the inductor ripple current, the switching frequency is also selected arbitrarily to lead more power loss[2]. Therefore we propose a inductor design procedure to minimize the power loss for boost converter using the genetic algorithm.

2. Proposed Inductor Design Procedure

The proposed inductor design procedure is shown in Fig. 1. The inductor ripple current and switching frequency are not given as specifications.

The total power loss function can be expressed as follows:

$$P_{loss}(L,f_s) = P_Q(L,f_s) + P_D(L,f_s) + P_C(L,f_s) + P_L(L,f_s) \qquad (1)$$

Where P_Q, P_D, P_C and P_L are each of MOSFET loss, diode loss, capacitor loss and inductor loss, and they are a function of the inductance and the frequency. The equation (1) is calculated using the

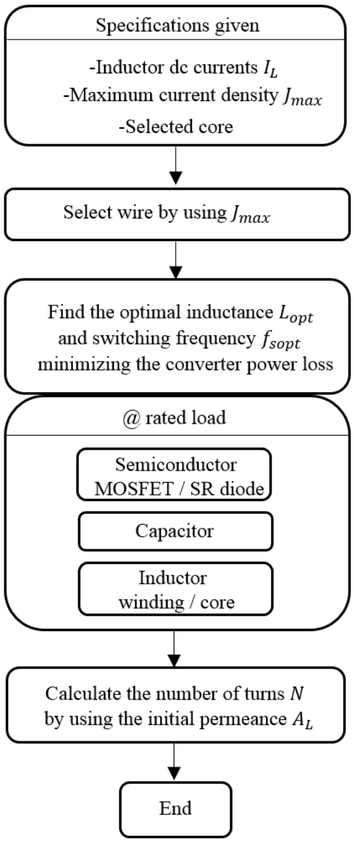

Fig. 1 Proposed inductor design procedure.

genetic algorithm. The genetic algorithm searches parallel from a population of points. Therefore, it has the ability to avoid being trapped in local optimal solution like traditional methods, which search from a single point. It is useful when an analytical solution is not feasible.

3. Simulation and Experimental results

The specification of the boost converter and of the inductor for the simulation and the experiment can be found in the Table. 1 and Fig. 2, respectively.

The 3D plot of total power loss using the genetic algorithm of MATLAB is shown in Fig. 3. Where the X axis is $L_x = L_{opt}/L_{\max}$, the Y axis is $f_y = f_{sopt}/f_{sr}$.

The simulation result shows total power loss according to the inductance and the frequency. The total power loss is minimum at $L_x = 0.1952$, $f_y = 0.886$. Where $L_{\max}$ and f_{sr} are each of $L_{\max} = 6.1mH$,

$f_{sr} = 65kHz$. Thus the optimal inductance is $L_{opt} = 1191\mu H$ and the optimal switching frequency is $f_{sopt} = 57.5kHz$.

Table.1 The parameters for simulation and experiments.

	Parameter	Value
Boost converter	Input voltage	220[V]
	Output voltage	380[V]
	Output power	817[W]
MOSFET	Drain-source resistance	0.38[Ω]
Diode	Forward voltage	1.5[V]
Capacitor	Capacitor ESR	0.564[Ω]
Core	Core material	High Flux
	Core permeability	60μ
	Core type	Toroidal
	Core size	26.92mm(OD) 11.18mm(HD)
Wire	Maximum current density	$700A/cm^2$

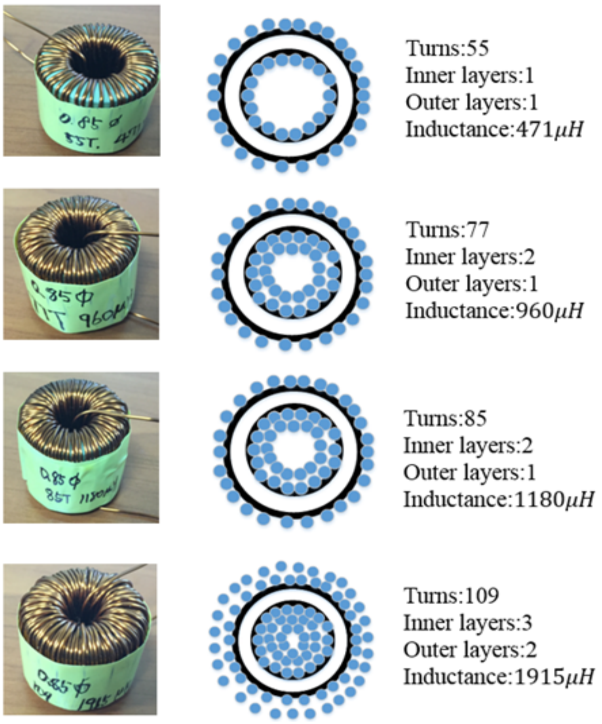

Fig. 2 Inductor used for experiment.

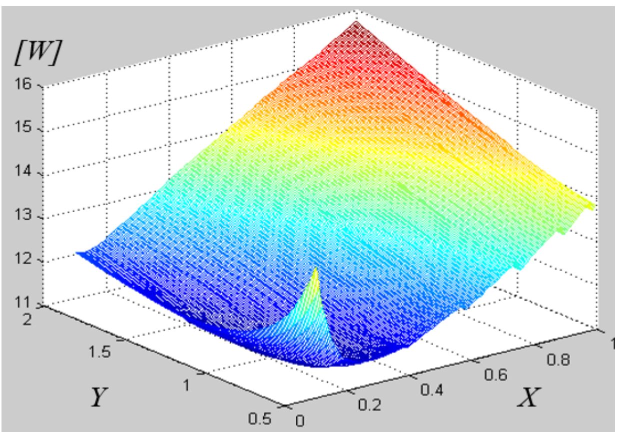

Fig. 3 3D plot of total power loss for boost converter.

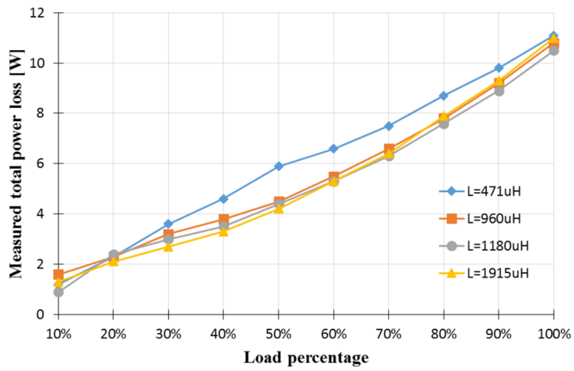

Fig. 4 Measured total power loss in case1.

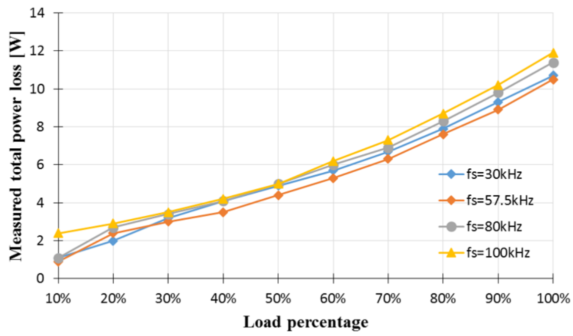

Fig. 5 Measured total power loss in case2.

The experimental was done in two cases. In case 1, the switching frequency is fixed in $57.5kHz$ and the inductances are $471\mu H$, $960\mu H$, $1180\mu H$ and $1915\mu H$, respectively. In case 2, the inductance is fixed in $1180\mu H$ and the switching frequencies are $30kHz$, $57.5kHz$, $80kHz$ and $100kHz$, respectively.

From Fig. 4 and Fig. 5, we can see that the total power loss in rated power condition is minimum when the inductance and the switching frequency are $1180\mu H$ and $57.5kHz$, respectively.

4. Conclusion

A proposed method for designing the inductor in the boost converter has been proposed to help finding the optimal inductance and switching frequency at rated power and minimizing the total power loss. By simulation and experiment the validity of proposed inductor design method has been verified.

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References

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