A method for inductor design to improve efficiency in PFC boost converter

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ABSTRACT

In this paper a method is proposed to optimize the inductor design of PFC boost converter with maximum efficiency at rated load. The variables of switching frequency, the number of turns, core size and permeability are selected to improve the efficiency. The experimental result shows the proposed inductor design method can lead a higher efficiency when compared with the typical inductor design method.

1. Introduction

Power Factor Correction (PFC) technique makes the input current waveform in phase to the voltage. So the power system can run much efficiently. As a popular topology to converter a low DC voltage into a higher one, the boost converter is widely used in PFC application. The research of high efficient PFC boost converter is also important. Typical inductor design with toroidal core of PFC boost converter didn't consider the efficiency[1]. The design points switching frequency and inductor current ripple are given as specifications by intuition and experience. With the design points, the inductance required with DC bias current can be found. Then according to the inductor stored energy, the appropriate core permeability and size can be selected by the core selection chart. The next are the calculation of the number of turns and the selection of wire. Unfortunately, the somewhat arbitrarily selected switching frequency and inductor current ripple could lead to more total power loss. Therefor we propose a new method for inductor design to improve the efficiency.

2. Proposed Inductor Design Method

The procedure of proposed inductor design method is shown in Fig. 1. The starting of the procedure is the specifications of the converter, including input and output voltage, output power, the maximum current density, the core material, the saturation flux density and the number of core stacks. The next is a wire selection. The wire selection is according to the current capacity of American wire gauge (AWG) at the given maximum current density. In wire table, the AWG wire size can be decided after the calculation of current capacity. At last, we use the genetic algorithm to

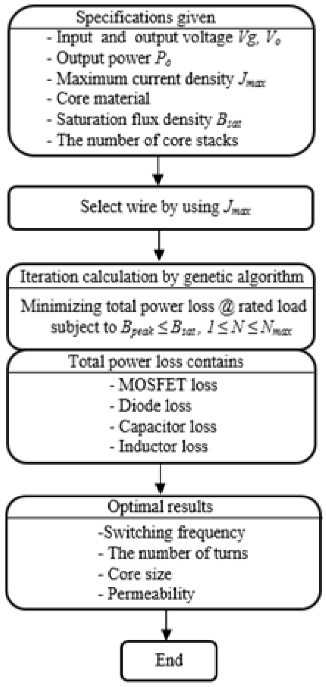

Fig. 1 Procedure of proposed inductor design method.

minimize the total power loss by iteration calculation. The genetic algorithm is a search heuristic that mimics the process of natural selection. At each step, the genetic algorithm randomly selects individuals from the current population and uses them as parents to produce the next generation through reproduction, crossover and mutation. Over successive generations, the population evolves toward a fitness value. The genetic algorithm searches parallel form a population of points. Therefore, it has the ability to avoid being trapped in local optimal solution like traditional methods, which searches a single point. In our genetic algorithm, the variables are switching frequency, the number of turns ,core size and permeability. The core sizes are indexed as a core selection table. The different core size index numbers are correspond to the different core sizes. The same as the core size, the permeability is also indexed as a permeability selection table. For example, the permeability of HighFlux core includes 26μ 60μ 125μ 147μ and 160μ, then the permeability index numbers can be correspond to 1 5. With the given constraints, generations option and populationsize option, the optimal switching frequency, the number of turns, core size and permeability can be accurately obtained.

The constraints contain $B_{peak} \le B_{sat}$ and $1 \le N \le N_{max}$, where B_{peak} is the peak flux density, B_{sat} is the saturation flux density, N is the number of turns and N_{max} is the maximum number of turns. The generations option in genetic algorithm determines the maximum number of generations, Increasing the generations option often improves the final result. The populationsize option specifies how many individuals there are in each generation. With a large population size, the genetic algorithm searches the solution space more thoroughly, thereby reducing the chance that the algorithm returns a local minimum that is not a global minimum. However, a large population size also causes the algorithm to run more slowly.

The objective function is the total power loss function. The total power loss P_{loss} can be expressed as follows

$$P_{loss} = P_Q + P_D + P_C + P_L \quad (1)$$

where P_Q, P_D, P_C and P_L are each of MOSFET loss, diode loss, capacitor loss and inductor loss.

3. Simulation and Experimental results

The design examples are shown as follows to demonstrate the proposed inductor design method can lead a higher efficiency by comparing with typical inductor design method. The PFC boost converter used in experiment has a rated output power 800W, input AC voltage 220V and output voltage 380V. The core shape is toroidal and the material chosen is Chang Sung Corporation's HighFlux. In order to reduce the inductor size, we substitute two cores for one core. The total cross sectional area of the two cores is similar to that of one core. In typical inductor design, the switching frequency are selected as 70 kHz and 130 kHz and the inductor current ripple is 25%. In proposed inductor design, the genetation option and populationsize option are set as 100 and 70. The inductor design results at rated load are shown in Table. 1.

Table.1 Inductor design results of typical and proposed method

	Typical Method		Proposed Method
	Design 1	Design 2	Design 3
Switching frequency	70 kHz	130 kHz	50 kHz
Core size (OD)	23.6 mm	22.9 mm	26.9 mm
Permeability	125µ	125µ	125µ
Number of turns	59	43	73
Inductance	774µH	356µH	1888 µH

where, OD is the outer diameter of core.

Three inductors shown in Fig. 2 have been made to have experiments with the PFC boost converter. Fig. 3 shows the simulation and experimental results and Fig. 4 shows the inductor current waveform of design 3 at rated load.

Fig. 2 Three inductors used for experiments.

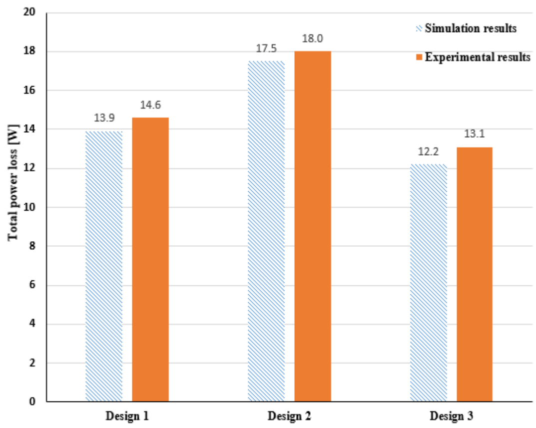

Fig. 3 Simulation and experimental results at rated load.

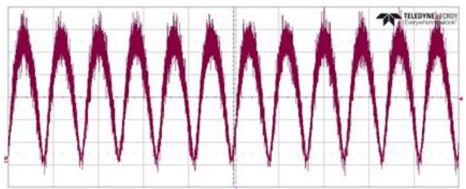

Fig. 4 Inductor current waveform of design 3 at rated load.

From the experimental results we can see, the proposed inductor design method in design 3 obtained a minimum total power loss about 13.1W when compared with the typical inductor design method in design 1 and design 2 obtained about 14.6 W and 18.0W. The experimental results validate that the proposed inductor design method is better than the typical design method and can lead a higher efficiency.

4. Conclusion

In this paper, a method for designing the inductor of the PFC boost converter has been proposed to help improving the efficiency at rated load. It can obtain the optimal switching frequency, the number of turns, core size and permeability by iteration calculation in genetic algorithm. By comparing with the typical inductor design method, the validity of proposed inductor design method has been verified in simulation and experiment

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References

[1] Magnetics®, "Powder cores",www.mag inc.com.