2.8kW CCM BOOST PFC detail design

Technical proposal

The max output power of PFC circuit is 2.8kW and select CCM BOOST PFC for this design, average current control mode

Input/output specifications

Minmum input AC voltage: $Vin_min := 165$

Normal input AC voltage: $Vin_nor := 220$

Maxmum input AC voltage: $Vin_max := 265$

Peak value of minimum AC input volatge: $Vin_minpk := 165 \cdot \sqrt{2}$

$Vin_minpk = 233.345$

PFC minimum output voltage: $Vpfc := 340$

Efficency of PFC power satge: $\eta := 0.98$

Maximum output power: $Pout := 2800$

Normal AC power frequency: $fp := 50$

Angular frequency of AC power: $\omega p := 2\pi \, fp$

Switching frequency: $fs := 50 \cdot 10^3$

Angular frequency of PFC: $\omega s := 2\pi \, fs$

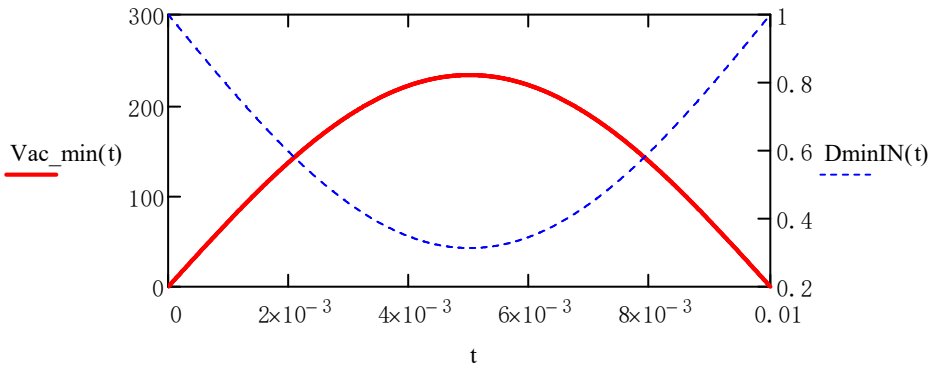
$j := \sqrt{-1}$

RMS value of AC input current: $Iin_maxRMS := \dfrac{Pout}{\eta \cdot Vin_min}$

$Iin_maxRMS = 17.316$

$Vac_min(t) := Vin_min \cdot \sqrt{2} \cdot \sin(\omega p \cdot t)$

Duty cycle of minimum AC input volatge: $DminIN(t) := \dfrac{Vpfc - Vac_min(t)}{Vpfc}$



PFC Inductor design of EVAL-M3-IM564 evaluation board

select current ripple ratio:

$\gamma := 0.12$

Ripple current is :

$\Delta I := \gamma \cdot \sqrt{2} \cdot Iin_maxRMS$

Peak current of inductor is :

$Ipk := \sqrt{2} \cdot Iin_maxRMS + \frac{\Delta I}{2}$

$Dmin := 1 - \frac{Vin_min \cdot \sqrt{2}}{Vpfc}$

$Dmin = 0.314$ $Ipk = 25.958$

$L_min := \frac{\eta \cdot Vin_min^2}{\gamma \cdot fs \cdot Pout} \cdot Dmin$

$L_min = 4.982 \times 10^{-4}$

select indcutance:

$Lpfc := 519 \cdot 10^{-6}$

OD of inductor copper wire:

$OD_copper := 1.0 \cdot 10^{-3}$

$Swire := 3\pi \cdot \left(\frac{OD_copper}{2}\right)^2$ the three wires are interwoven

$Swire = 2.356 \times 10^{-6}$

$Idensity := \frac{Iin_maxRMS}{Swire \cdot 10^6}$

$Idensity = 7.349$

Core selection

$\mu 0 := 4 \cdot \pi \cdot 10^{-7}$ $\mu r := 60$ $Bmax := 0.75$

Effective magnetic volume of the core:

$Ve_core := \mu 0 \cdot \mu r \cdot Lpfc \cdot \left(\frac{Ipk}{Bmax}\right)^2$

$Ve_core = 4.688 \times 10^{-5}$

Select POCO toroid core NPH184060-L, the core dimensions are as below:

$OD := 47.63 \cdot 10^{-3}$ $ID := 23.32 \cdot 10^{-3}$ $HT := 18.92 \cdot 10^{-3}$ $le := 10.74 \cdot 10^{-2}$

$Aw := 4.27 \cdot 10^{-4}$ $Ae := 1.990 \cdot 10^{-4}$ $Ve := 21.373$

Turns number of inductor is:

$Ninductor := \sqrt{\frac{Lpfc \cdot le}{\mu 0 \cdot \mu r \cdot Ae}}$

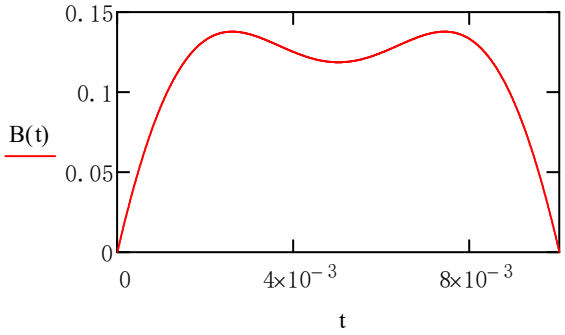
$Ninductor = 60.951$

$N := 62$

$Kw := \frac{N \cdot Swire}{Aw}$

$Kw = 0.342$

$B(t) := \frac{Vac_min(t) \cdot DminIN(t)}{N \cdot fs \, Ae}$



$$Bpk := \frac{375}{4 \cdot N \cdot Ae \cdot fs}$$

$Bpk = 0.152$

$$Bavg := \frac{\int_0^{10 \cdot 10^{-3}} B(t)\, dt}{10 \cdot 10^{-3}}$$

$Bavg = 0.111$

$$Pcore := \left[3.65 \cdot \left(\frac{Bavg}{0.1} \right)^{2.2081} \cdot \frac{fs}{10^3} + 0.0074 \cdot \left(\frac{Bavg}{0.1} \cdot \frac{fs}{10^3} \right)^2 \right] \cdot Ve \cdot 10^{-3}$$

$Pcore = 5.399$

The windings conductive loss is calculated:

$Lperturn := (OD - ID + 3 \cdot OD_copper + 2 \cdot HT)$ $Lperturn = 0.065$

$\rho cu := 0.0206$ resistivity @ $Ta := 60\,°C$

$$Rdc := \rho cu \cdot \frac{N \cdot Lperturn}{Swire \cdot 10^6}$$

$Rdc = 0.035$

$Pcu := Iin_maxRMS^2 \cdot Rdc$ $Pcu = 10.589$

The total loss of PFC choke is summarized:

$Pchoke := Pcore + Pcu$ $Pchoke = 15.988$

Inductance calculation:

$$L_0A := \frac{\mu 0 \cdot \mu r \cdot Ae \cdot N^2}{le}$$

$L_0A = 5.37 \times 10^{-4}$

Inductance versus DC bias:

$$He := \frac{N \cdot Iin_maxRMS \cdot \sqrt{2}}{le} \cdot 4 \cdot \pi \cdot 10^{-3}$$

$He = 177.648$

The toroid core Permeability at 150 Oersted is decreased to 55% of 0 Oersted.

$\Delta\mu := 0.55$

$L26A_bias := \Delta\mu \cdot L_0A$ $L26A_bias = 2.954 \times 10^{-4}$

$$Bmax := He \cdot \mu 0 \cdot \mu r \cdot \Delta\mu \cdot \frac{10^7}{4 \cdot \pi} \cdot 10^{-4} \qquad Bmax = 0.586$$

Ripple current of PFC choke:

$$\Delta ripple := \frac{\sqrt{2} \cdot Vin_min}{L26A_bias \cdot fs} \cdot Dmin \qquad \Delta ripple = 4.956$$

$$\gamma_max := \frac{\Delta ripple}{Iin_maxRMS \cdot \sqrt{2}} \qquad \gamma_max = 0.202$$