Analysis of quasi-resonant inverter for domestic induction heating applications

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I. Introduction to induction heating systems

- Introduced in food cooking once power semiconductors were employed.

- Benefits: safety, cleanliness, heating speed, non-contaminating and high efficiency.

- Drawbacks for massive use in domestic applications: high cost, control complexity, and harmonic distortion.
I. Introduction to induction heating systems

Schematic representation of an induction heating cooktop

I. Introduction to induction heating systems

Single switch topology

Reduce losses and supplying two or three parallel loads
II. Quasi resonant inverters in IH systems

Zero Current

Resonant switches

Soft-switching

Zero Voltage

Hard-switching
II. Quasi resonant inverters in IH systems

Quasi-resonant inverter circuit
II. Quasi resonant inverters in IH systems

Technique to trigger the switches

PWM

Quasi-resonant inverter circuit implemented in PSIM®

\[ C = 0.168 \, \mu F \]
II. Quasi resonant inverters in IH systems

Voltage and current at different stages of the QRI

Stage E-F

Equivalent circuit of QRI operation
II. Quasi resonant inverters in IH systems

Equations (2) to (6) represent the currents of the inductance on each stage in the time domain.

\[ i_{L(A-B)}(t) = 13.568 \cos(219900t + 0.5951) e^{-1060t} \]  \hspace{1cm} (2)

\[ i_{L(B-C)}(t) = 9.132 \cos(310980t + 1.7379) e^{-1060t} \]  \hspace{1cm} (3)

\[ i_{L(C-D)}(t) = 8.924 \cos(219900t + 2.9448) e^{-1060t} \]  \hspace{1cm} (4)

\[ i_{L(D-E)}(t) = 13.564 \cos(219900t - 2.1917) e^{-1060t} \]  \hspace{1cm} (5)

\[ i_{L(E-F)}(t) = 12.576 e^{-2127.66t} \]  \hspace{1cm} (6)
III. Analysis of the IH system operation

Voltage and current waveforms in the inductor for $D = 0.6$
III. Analysis of the IH system operation

Instant power waveform in the inductor
III. Analysis of the IH system operation

RMS value of the current: 7 A

Total harmonic distortion (THD): 0.39%

Waveform

Spectral diagram

Line current behavior
III. Analysis of the IH system operation

Relationship between reactive power and duty cycle $D$

Reactive power vs. duty cycle behavior

$D = 0.1$ - $0.9$
Steps = 0.025
III. Analysis of the IH system operation

*Feedback loop*

Feedback loop circuit

Feedback loop simulation

vertical shifting of 2.5 V.
III. Analysis of the IH system operation

Feedback loop

\[ D = -0.159 \ln(V_{control}) + 0.5843 \] (7)

\[ D_{Ref} = -0.159 \ln(V_{Ref}) + 0.5843 \] (8)

\[ D_i = D_{i-1} + \Delta D \] (9)

\[ D_i = D_{i-1} + 0.159 \ln \left( \frac{V_{Control(i-1)}}{V_{Ref}} \right) \] (10)
IV. Conclusions and future work

- From this analysis was obtained:

  * Current is periodical, and its waveform is a bounded cosine by a decreasing exponential, with positive and negative semi-cycle in four of the five studied intervals.

  * The quasi-resonant inverter has a harmonic distortion content of 0.39%.

- The paper presents the equations to represent a design tool for the signal generator of the power switches.

- This study can be used as a base for the design of a prototype of the power stage of an IH system.
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Thank you for your attention

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