XSICEL 2021

Transición energética en la 4ta revolución industrial

Universidad Tecnológica de Pereira

UNIVERSIDAD NACIONAL DE COLOMBIA

XSICEL 2021
Transición energética en la 4ta revolución industrial

Analysis of quasi-resonant inverter for domestic induction heating applications

Mariana Durango Flórez (speaker)
Luz Adriana Trejos Grisales
Adolfo Escobar

Facultad de Ingenierías
Instituto Tecnológico Metropolitano
Medellín, Colombia

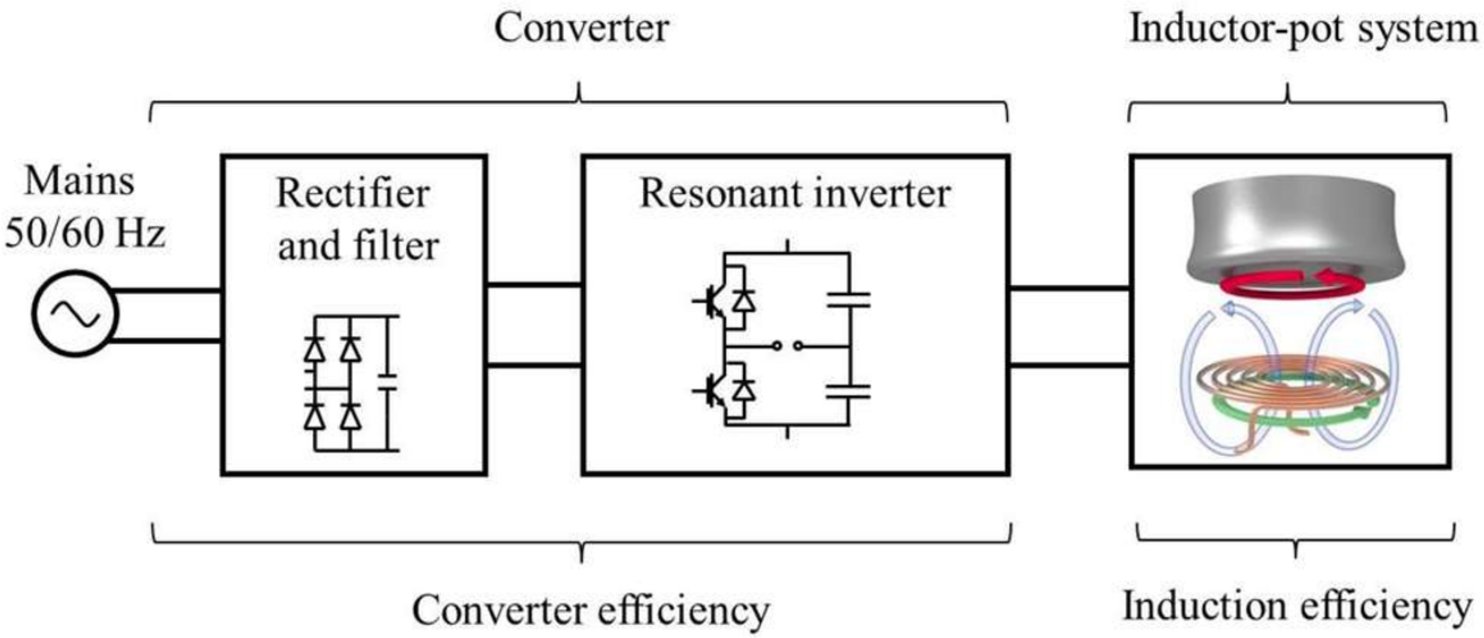
I. Introduction to induction heating systems

- 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

IH cooking example

XSICEL 2021 Transición energética en la 4ta revolución industrial

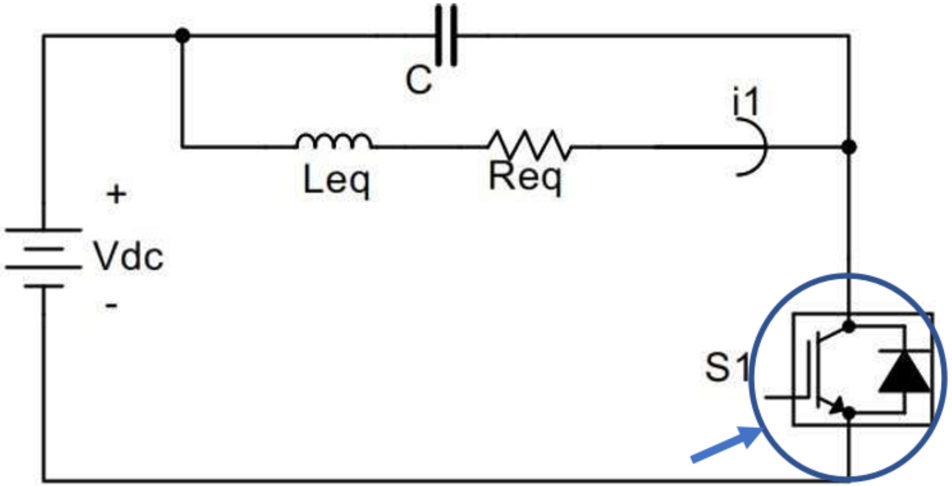
I. Introduction to induction heating systems



Schematic representation of an induction heating cooktop[1]

[1]J. Serrano, et al., "Design and Implementation of a Test-Bench for Efficiency Measurement of Domestic Induction Heating Appliances," Energies, vol. 9, no. 8, p. 636, Aug. 2016.

I. Introduction to induction heating systems

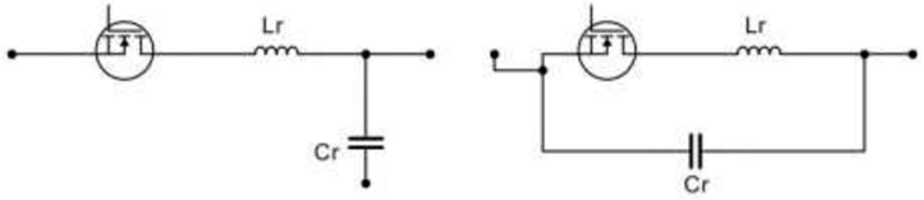


Single switch

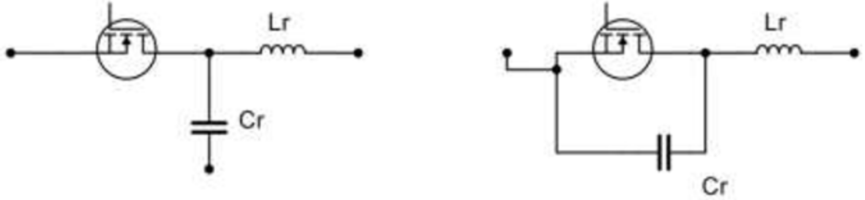
Single switch topology

Reduce losses and supplying two or three parallel loads

II. Quasi resonant inverters in IH systems



Zero Current



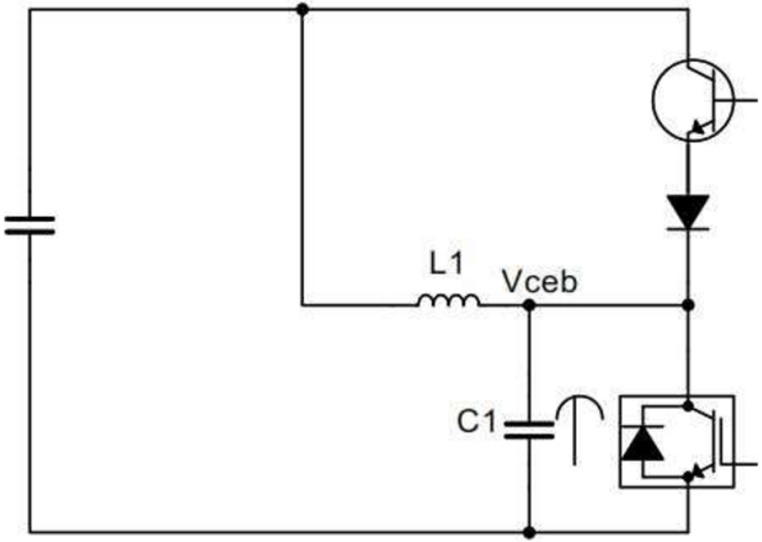
Zero Voltage

Resonant switches

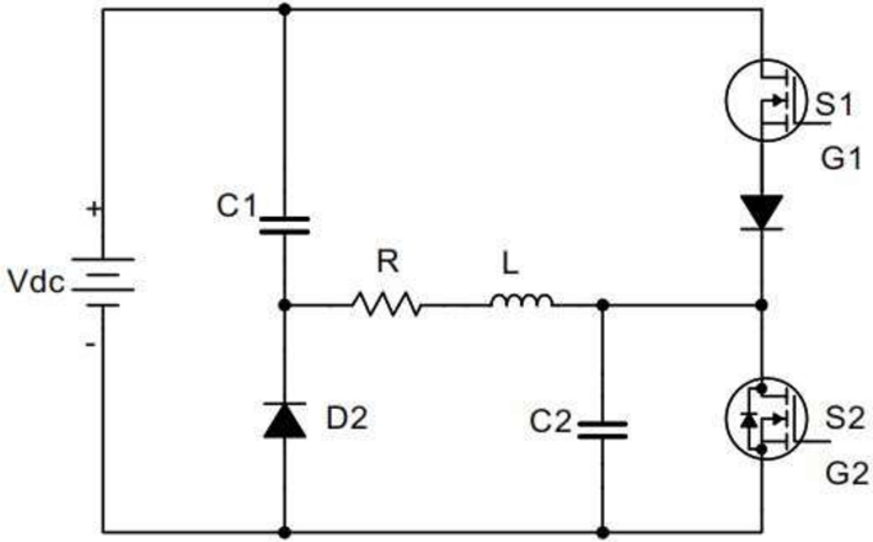
Soft-switching

Hard-switching

II. Quasi resonant inverters in IH systems



Basic form

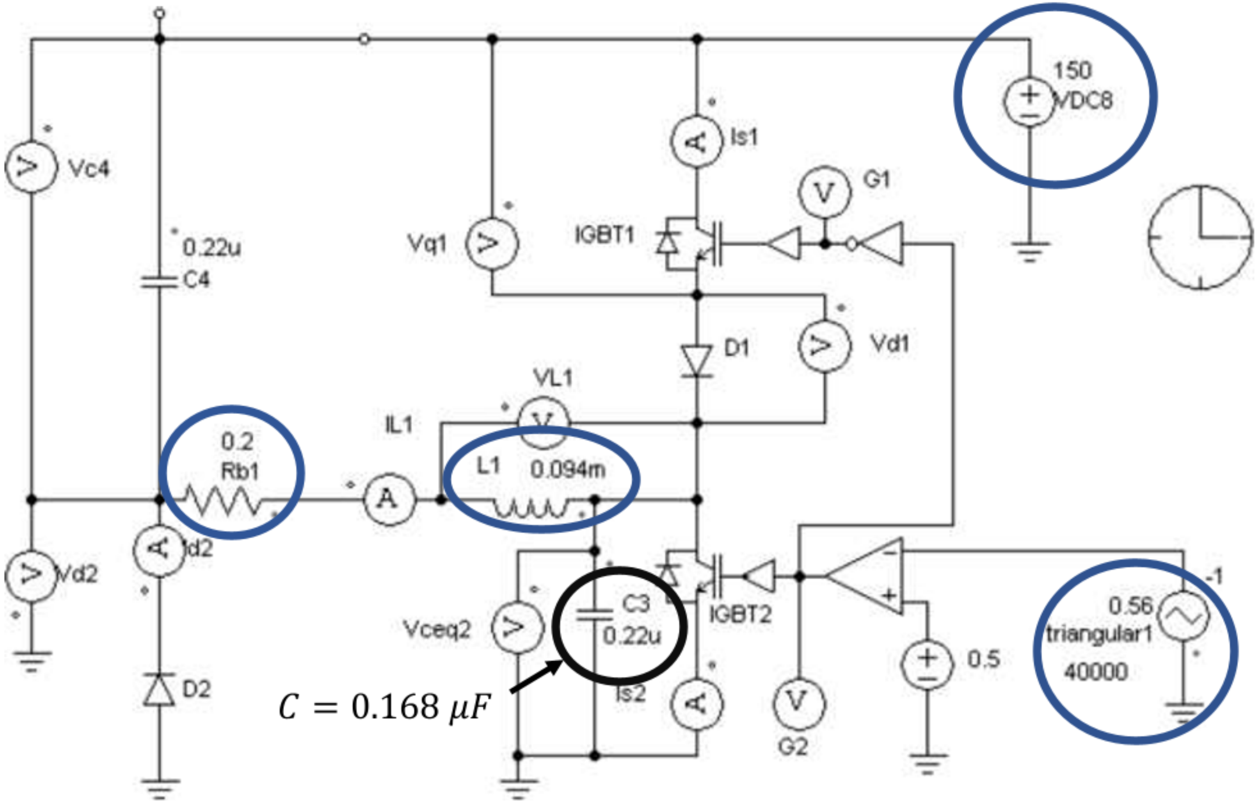


With a capacitor and a diode

Quasi-resonant inverter circuit

II. Quasi resonant inverters in IH systems

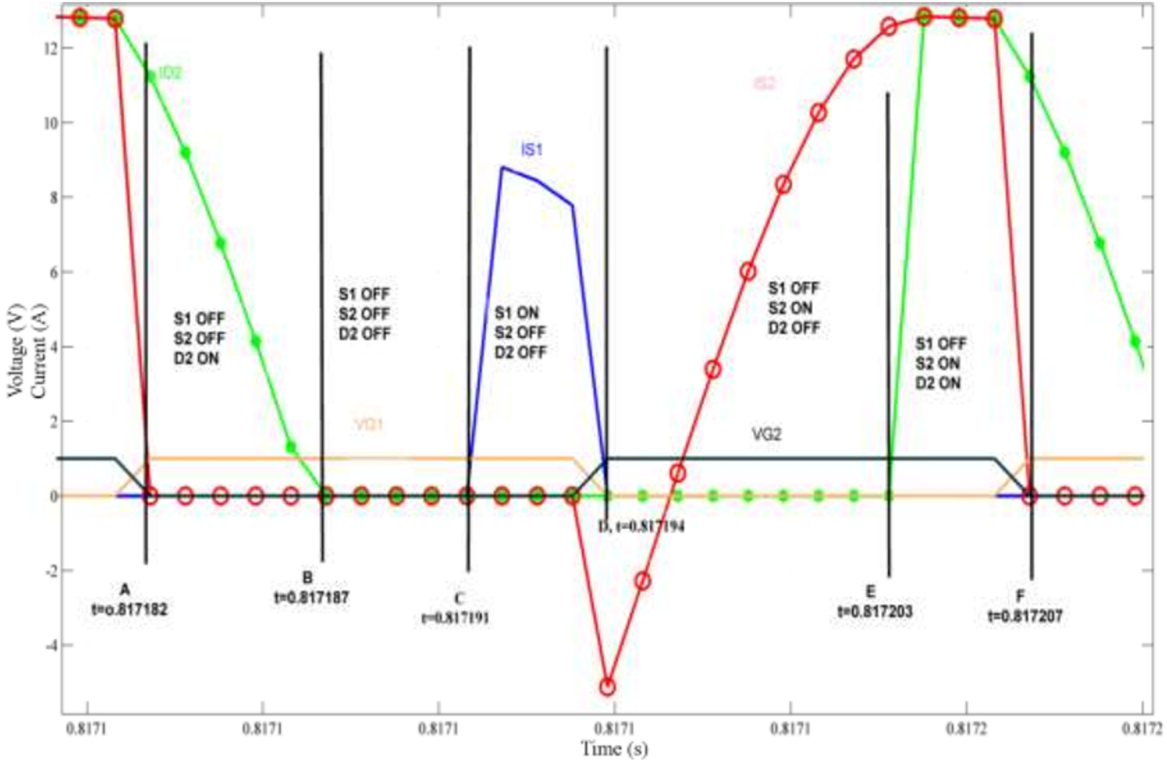
Technique to trigger the switches
PWM



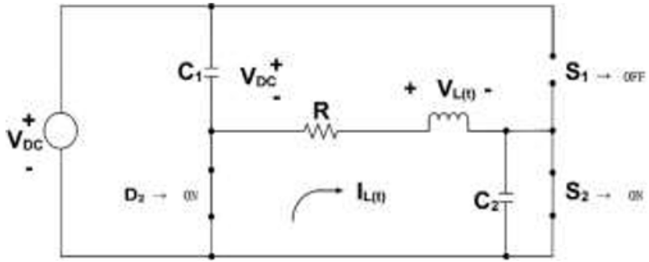
$C = 0.168\ \mu F$

Quasi-resonant inverter circuit implemented in PSIM®

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.

$$i_{L(A-B)}(t) = 13.568\cos(219900t + 0.5951)\,e^{-1060t} \qquad (2)$$

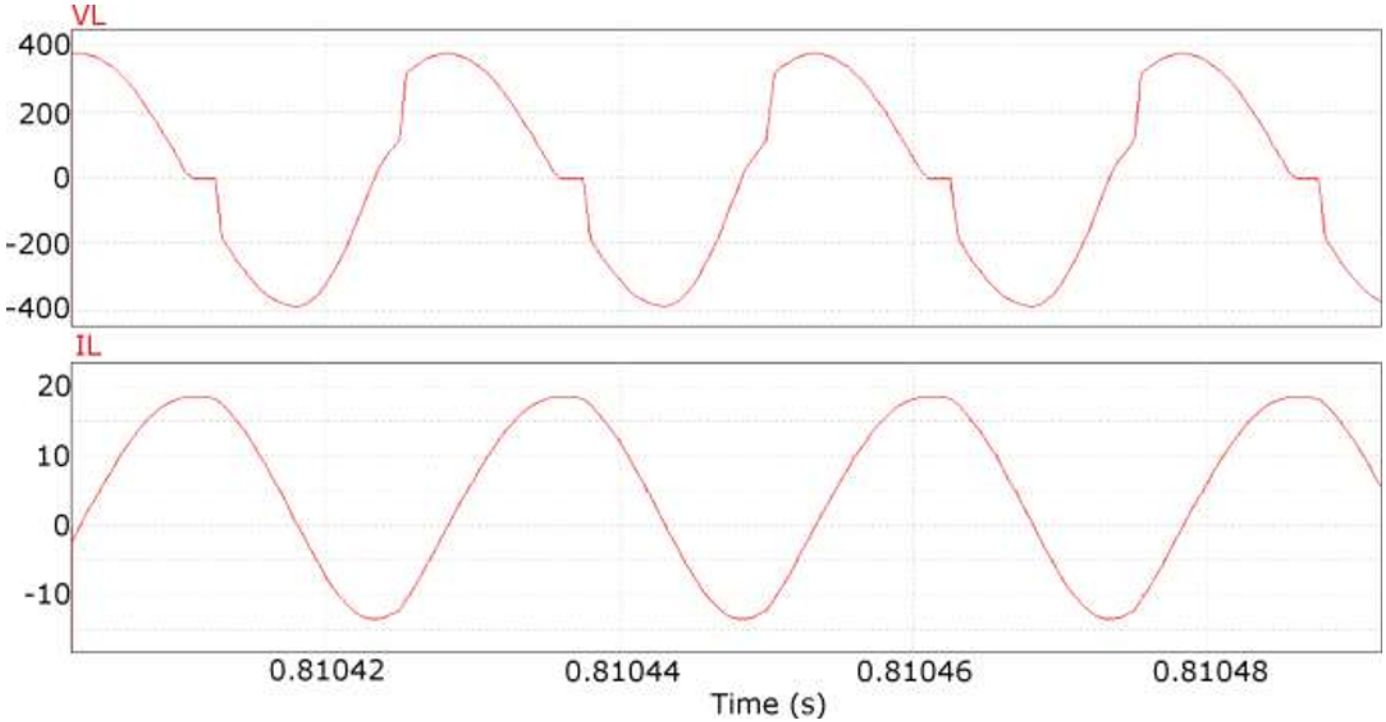
$$i_{L(B-C)}(t) = 9.132\cos(310980t + 1.7379)\,e^{-1060t} \qquad (3)$$

$$i_{L(C-D)}(t) = 8.924\cos(219900t + 2.9448)\,e^{-1060t} \qquad (4)$$

$$i_{L(D-E)}(t) = 13.564\cos(219900t - 2.1917)\,e^{-1060t} \qquad (5)$$

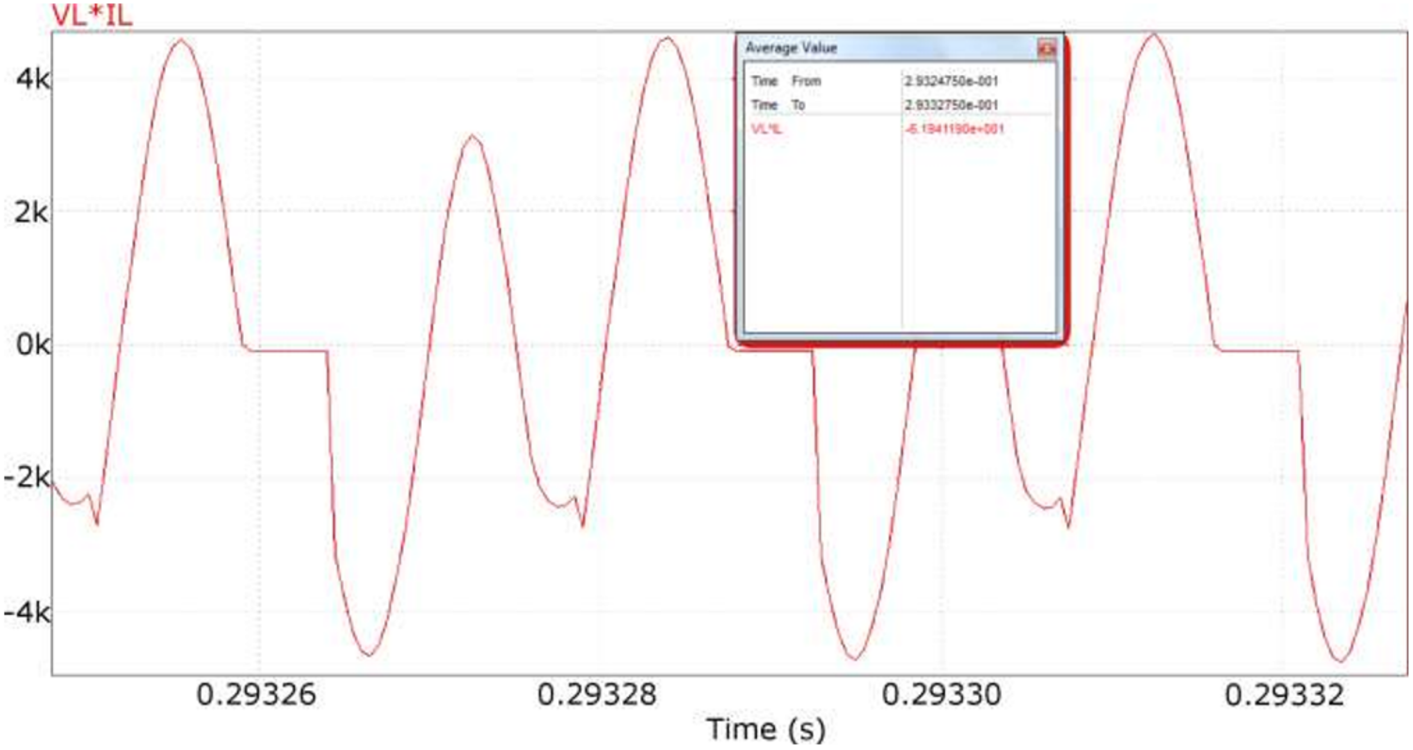
$$i_{L(E-F)}(t) = 12.576e^{-2127.66t} \qquad (6)$$

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

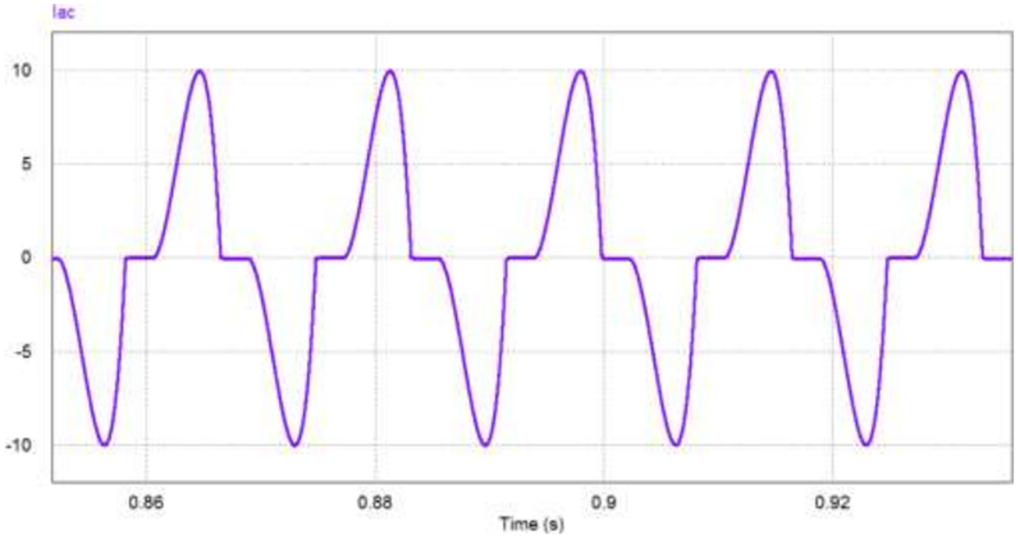


Instant power waveform in the inductor

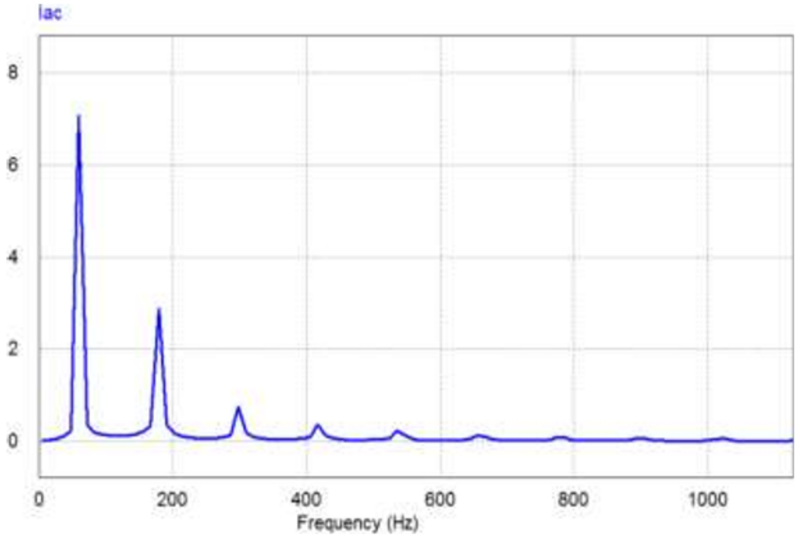
III. Analysis of the IH system operation

RMS value of the current: 7 A

Total harmonic distortion (THD): 0.39%



Waveform



Spectral diagram

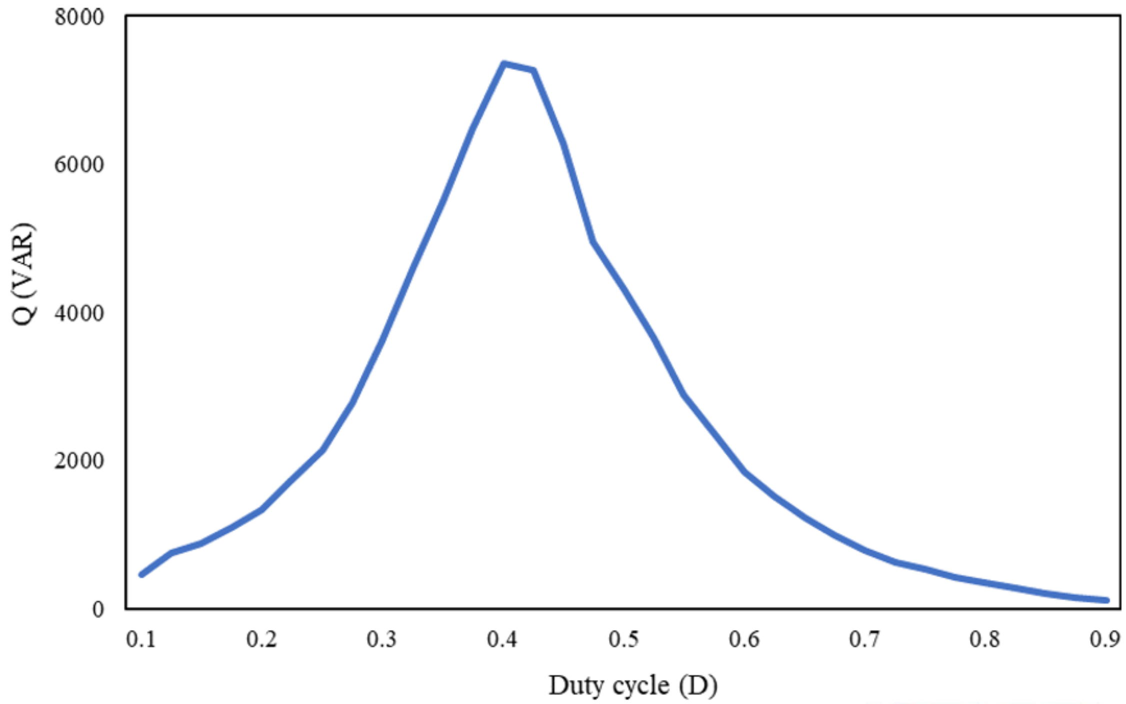
Line current behavior

III. Analysis of the IH system operation

Relationship between reactive power and duty cycle D

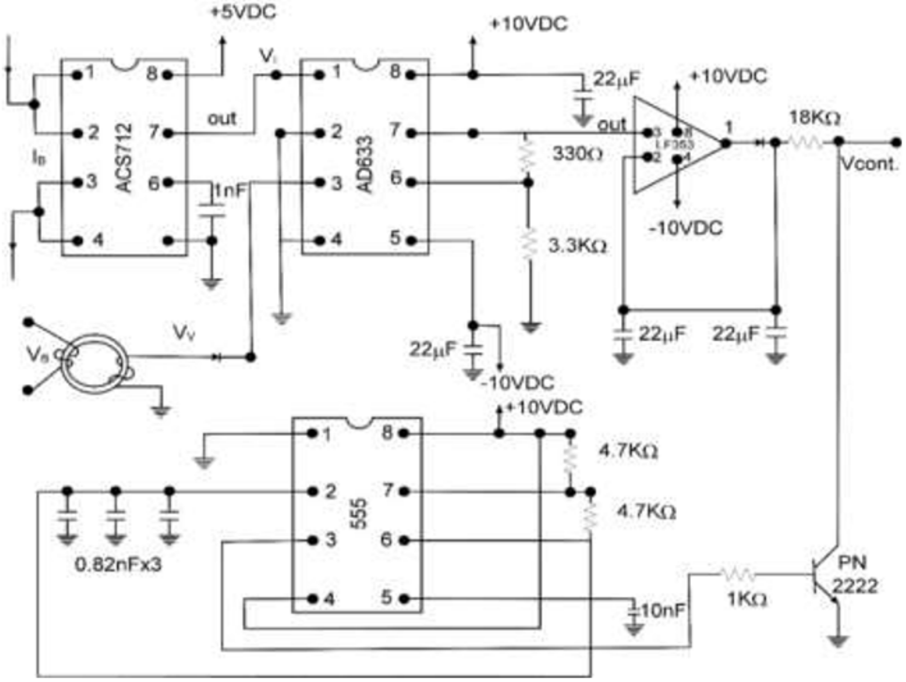
Reactive power vs. duty cycle behavior

D = 0.1-0.9
Steps = 0.025

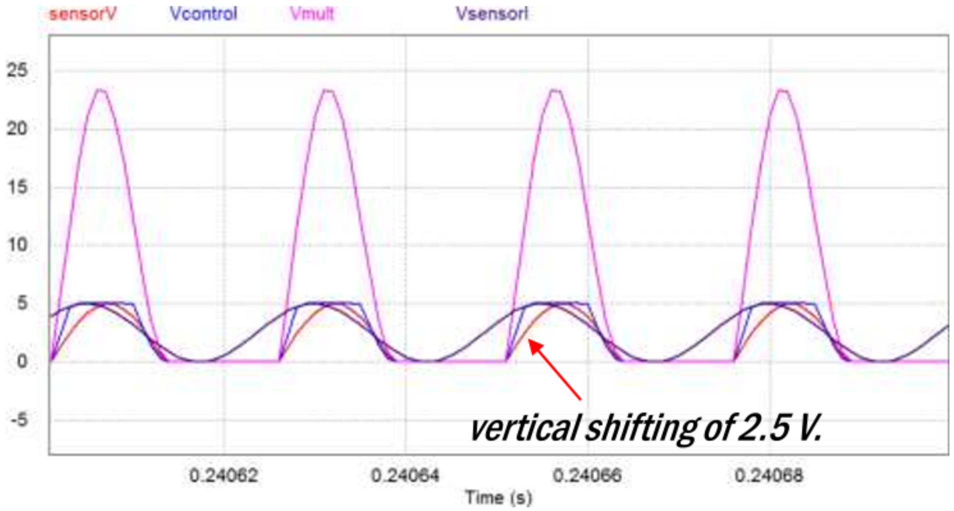


III. Analysis of the IH system operation

Feedback loop



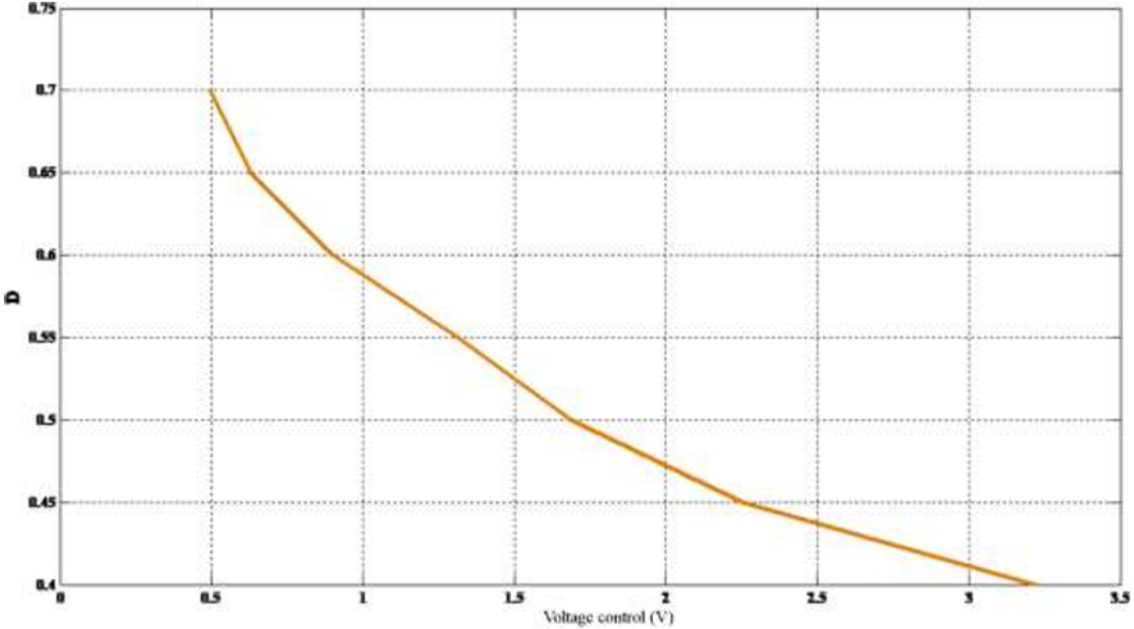
Feedback loop circuit



Feedback loop simulation

III. Analysis of the IH system operation

Feedback loop



Control voltage vs duty cycle behavior

$$D = -0.159\ln(V_{Control}) + 0.5843 \quad (7)$$

$$D_{Ref} = -0.159\ln(V_{Ref}) + 0.5843 \quad (8)$$

$$D_i = D_{i-1} + \Delta D \quad (9)$$

$$D_i = D_{i-1} + 0.159\ln\left(\frac{V_{Control(i-1)}}{V_{Ref}}\right) \quad (10)$$

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.

Analysis of quasi-resonant inverter for domestic induction heating applications

Thank you for your attention

marianadurango134392@correo.itm.edu.co
Instituto Tecnológico Metropolitano
Medellín, Colombia