DECIMOQUINTA CONVOCATORIA PARA EL FOMENTO DE LA INVESTIGACIÓN Y LA INNOVACIÓN 2020

Título	
SOFT-SWITCHING DESIGN FOR DC-DC CONVERTERS APPLIED TO SMART BUILDINGS	
Campo de acción	**Transdisciplinariedad - Aporte al PIM**
Desarrollo tecnológico con apuesta social (x) Desarrollo ambiental sostenible (x) Cambio educativo y social desde la multi e interculturalidad (x)	Compromiso con el proyecto educativo. Proyección social e investigación pertinentes. Enriquecimiento regional de los programas con estándares comunes. Personas que transforman sociedad.

Articulación con funciones sustantivas y el sector social y productivo

El proyecto se articula con las siguientes Líneas de acción del Plan General de Desarrollo:

2. Compromiso con el proyecto educativo
2.3 Maximizar la dedicación docente en las funciones sustantivas.

3. Proyección social e investigación pertinentes
3.2.3 Implementar los programas y proyectos de proyección social.
3.2.4 Verificar la articulación de las funciones sustantivas en los programas y proyectos implementados.
3.4.4 Consolidar el desarrollo de los procesos de investigación en posgrado, fomentando los procesos de investigación en pregrado.

5. Personas que transforman sociedad
5.1.5 Construir la política de inclusión de la USTA.

Grupo de investigación	**Línea de investigación en la que se inscribe el proyecto**
MEM Modelado, Electrónica y Monitoreo	Sistemas de Energía Eléctrica

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División de Ingenierías	Facultad de Ingeniería Electrónica	Pregrado en Ingeniería Electrónica	MEM Modelado, Electrónica y Monitoreo
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División	**Facultad**	**Programa**	**Grupo de investigación**
División de Ingenierías	Facultad de Ingeniería Electrónica	Pregrado en Ingeniería Electrónica	MEM Modelado, Electrónica y Monitoreo
Nombre del Co-investigador	**Enlace CvLAC**	**Enlace ORCID**	**Enlace Google Académico**
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División	**Facultad**	**Programa**	**Grupo de investigación**
División de Ingenierías	Facultad de Ingeniería Electrónica	Pregrado en Ingeniería Electrónica	MEM Modelado, Electrónica y Monitoreo

Resumen de la propuesta	Palabras clave
The Soft-Switching technique is adopted looking forward to reaching some advantages in different characteristics on the whole system. A power factor closes to zero by adding a resonant circuit that dismisses the ripple of current or voltage, depending on the converter to be implemented. Therefore, it is necessary to say that, there are different topologies based on the chopping mode adopted by any type of converter. The variations are basically the option of recovering or not recovering energy from the movement of braking of motors. It is not necessary to mention the relevance of recovering energy from the brakes of the motors on the buildings is enormous.	Smart Buildings, Soft-Switching, Energetic Efficiency, Switched Converters

Problema de investigación

In order to truly understand the main flow of this project, we have to start with a topic that has been recently discussed a lot, climate change, it is a very important topic in our time, mainly because the sustainable development could be directly affected by it, Earth's climate has changed throughout the centuries, having 7 glacial ages, and then adapting itself to human life, the problematic climate change started in the 20th century and has escalated to a point that makes us take action in order to maintain all kinds of lives on Earth, some of the side effects are for example the global temperature has raised around 0.9 degrees Celsius, the Oceans have also increased their temperatures, the ice in Greenland and the Antarctic has reduced, to list some of the problems encountered by the NASA, since the current problem is very significant to all forms of life on Earth and the further development in most of the investigation areas.

As an alternative to improve the air quality we believe a partial solution are the Smart Building, there is a problem with the implementation of this technologies and it is divided in two: On one side the high cost of the materials and implementation itself, and on the other side the difficulty in the implementation of the technology and the lack of infrastructure that allows the batteries into buildings to be charged. In Colombia, there is no major development of Smart Buildings and charging stations which makes complicated to construct of one of this, and worse to be able to charge it easily and efficiently.

Delving into this topic, and as it was mentioned before the materials and the implementation are expensive and also there is an important issue to stand out and is the poor energy efficiency, because when the converter works with the typical switching techniques like hard switching, the

components are taken to the limit work zone risking the functionality of the system by producing damages in the converters or other parts that could be important on the complete system that can or cannot be part of the converter implemented.

By this constant work with ripples of voltage or current, depending on the converter, appear a thermal dissipation of power, causing a progressive damage to the material until in some point affects the work of the converter or, in the worst cases, leaving the elements or the whole system useless.

Which is why, this project is guided by the following main question:

Which is the improvement of commuted converters for Smart Buildings by applying Soft Switching techniques in comparison with the common hard switching technique?

Justificación

The main motivation to delve into this topic of Smart Buildings is directly related to the actual society and the environmental issues that fossil fuels and pollution are causing nowadays, moved by this reappeared factors and driven by two main accords The Kyoto protocol and the Paris Agreement, created to minimize these issues and improve the air quality and many more issues created under the actual conditions of pollution, there are new developments and innovations.
Going deeper into this subject, one of the main issues with the Smart Buildings is that they are expensive and in order to decrease the actual cost, this project will be guided towards the investigation on how to increment the lifetime of the elements used for the buildings, such as the batteries since around 30% - 40% of the initial costs of Smart Buildings is the cost of the battery, and these batteries last for about 1500 cycles which means that the battery life is around 4-5 years of use. Which can be challenging because of the difficulties in the implementation of energy efficient systems.

The Soft-Switching technique is adopted looking forward to reaching some advantages in different characteristics on the whole system. A power factor closes to zero by adding a resonant circuit that dismisses the ripple of current or voltage, depending on the converter to be implemented. Therefore, it is necessary to say that, there are different topologies based on the chopping mode adopted by any type of converter. The variations are basically the option of recovering or not recovering energy from the movement of braking of motors. It is not necessary to mention the relevance of recovering energy from the brakes of the motors on the buildings is enormous.

More than simply applying a concept and adapt it to the converter topology existing in a Smart Building, is the change that this concept will generate. Due to an efficiency near to the 100%, there is no high-power dissipation by temperature, is reduced the stress on the components

and by the way, their useful life and the possibility of increase the reliable in specific and general components. As a plus, treatment with the battery is direct and highly more efficient than leaving the system working alone with the typical hard switching.

The improvement and all the factors previously considered, are shared and directed to all who want to invest, search, investigate in the Smart Buildings theme. Moreover, looking for a improve to the planet, one of the important factors taking account is the batteries issue, being this element one of the hardest in the recycle process, it becomes, in the way of this project could help, one of our interest sector by prolonging the useful life of the batteries at least in their application. Finally, adding to all of this, one of the goals is to make lower the cost in a long term of the building, adding soft-switching it becomes possibly consider some benefits even for the costumer in a monetary way.

Objetivo general

Develop DC-DC Converters that use the Soft Switching technique as an application for Smart Buildings.

Objetivos específicos

- ✓ Use the Simscape Power Systems toolbox for SIMULINK, creating blocks to recreate the semiconductor devices as a real model simulation, with switching and temperature losses.
- ✓ Design and implement a SEPIC-ZETA and Buck-Boost Bidirectional DC-DC Converters with the typical configuration and another one adding the resonant elements in order to implement the Soft Switching technique.
- ✓ Compare the techniques hard switching and soft switching used for the SEPIC-ZETA and the Buck-Boost Bidirectional DC-DC Converters for describe the advantages and disadvantages of each one according to their behaviors in Smart Buildings.

Estado del arte y marco conceptual

Batteries are a form of energy storage, they store and release energy, the battery technologies have two characteristics that affect their design cost of operation, performance and durability: power density that is the amount of energy that can be delivered in a given period of time and energy density that is the capacity to store energy. [1]

Batteries consist mainly of five components:

- Electrodes: Anode and cathode
- Separators
- Terminals
- Electrolyte
- Case or enclosure

A battery is an electrochemical cell in which a voltage is generated at the battery terminal by a difference of potential between the positive and negative terminals, when an electrical load is connected the circuit is completed, the current flows from the positive terminal to the load and returns to the battery through the negative terminal, the process continues while using the energy stored in the battery until it reaches a discharged state, if the load is replaced by a power source that reverses the current flow the battery can be charged. There are two terminals per battery, a negative one and a positive one; the electrolyte can be a liquid, gel or solid material [2].

There are different types of batteries based on their main components, such as Lead Acid, Nickel-based, Sodium-based, Lithium, Metal-air or supercapacitors. Traditional batteries such as Pb-acid or NiCd use a liquid electrolyte, this may be acidic or alkaline depending on the battery. In many of the actual batteries like NiMH, Li-ion the electrolyte is a gel, paste, or resin. And Lithium-polymer batteries use a solid electrolyte, to give a few examples [3][4][5].

Batteries are the key components of autonomy in smart buildings, it is the component with the highest cost since it is the only energy store, it is also big and heavy. There are two ways to measure batteries:

1. Specific energy:
   Quantity of energy that one kilogram of battery can restore. The unit is expressed in Wh/kg.

2. Specific Power:
   The supply of the electric motor with a quantity of energy for a few dozen seconds to achieve acceleration.

Linear-mode and switch-mode converters are used in the design of commercial DC to DC power supplies. Linear power regulators are based on voltage or current dividers, they offer four major advantages: the design is simple, there is no electrical noise in the output, the dynamic response time is fast and it is low cost, but this also means the applications are limited because it has disadvantages: the input voltage is higher than the output voltage since the circuit is used as a step-down regulator, each regulator is limited to one output and the efficiency is low (around 30% to 60% for an output voltage lower than 20V) [6][7].

Switching regulators are used for higher power levels they use semiconductor switches in on and off states, they improve all the disadvantages of linear regulators: the efficiency is above 90%, power transistors operate at the most efficient points (cut-off and saturation), it allows more than one output and the size and cost are much lower especially at high power levels, but even this also have limitations: the complexity is greater compared to linear power supplies, it has high EMI and the switching has to be lower than 100kHz because of the high stress on semiconductor devices.

The functions of DC-DC Converters are:

1. Convert a dc input voltage into a dc output voltage
2. Regulate the dc output voltage against load and line variations
3. Reduce the ac voltage ripple on the dc output voltage below the required level
4. Provide isolation between the input source and the load
5. Protect the supplied system and the input source from EMI
6. Satisfy various international and national safety standards

DC-DC Converters are divided in two main types:

1. Hard switching PWM Converters:
   The main advantages of this type of converters are the low component count, high efficiency, constant frequency operation, simple control, commercial availability of components, and ability to achieve high conversion ratios for step-up and step-down applications. The main disadvantage is that PWM rectangular voltage and current cause losses while turning on or off, and limits the operating frequency to a MHz range, also the rectangular waveforms generate EMI, some of this converter are:

   - DC Choppers
     - Buck Converter
     - Boost Converter
     - Buck-Boost Converter
     - Cuk Converter

Metodología

The methodological design will be explained by the next two charts:

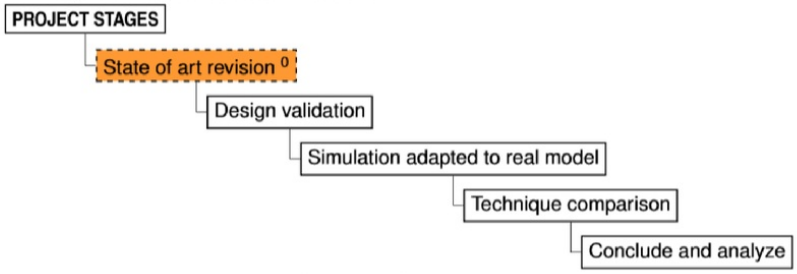

Figure: Project States.

Then, an analysis of each of the project states will be shown.

PROJECT STAGES

- **State of art revision:** Revision of the technique that will be used and the regular ones
- **Design validation:** Validate the design of the soft-switching converter using the information obtained in the state of art .
- **Simulation adapted to real model:** Adapt the model using the tool Simulink®, creating a realistic simulation.
- **Technique comparison**
  - Hard Switching
  - Soft Switching
- **Conclude and analyze results:** Analyze advantages and disadvantages of each technique and conclude using the results.

Resultados esperados

Los productos esperados de este proyecto de investigación son:

Producto	Descripción	Beneficiario
Un (1) artículo de Investigación	A1, A2, B o C. (Clasificación Publindex 2017)	Contribución al conocimiento del grupo de investigación y la Facultad. Socialización de información a nivel institucional, local, nacional e internacional.
Un (1) evento científico.	Congreso, simposio o ponencia científica.	Generar visibilidad al grupo de investigación, facultad y universidad.
Un (1) trabajo de grado.	Tesis pregrado	Integración de la investigación al proceso educativo de nuestros estudiantes.

Cronograma

ACTIVIDADES	RESPONSABLES	FEBRERO				MARZO				ABRIL				MAYO				JUNIO				JULIO				AGOSTO				SEPTIEMBRE				OCTUBRE				NOVIEMBRE			
		25																																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Scope Reading	All Researchers And Young Researcher																																								
Literature Review																																									
Define Scope of Review																																									
Solver Analysis																																									
Circuit Estimation																																									
Software Selection																																									
Simulation Procedure																																									
Run Simulated Experiments																																									
Analysis of Data																																									
Conclusions																																									

Presupuesto:

	Presupuesto Horas nómina					
Concepto	**Nombre**	**Escalafón**	**Horas mes**	**Sede / Seccional o Externo**	**Total ($)**	
Horas Nomina (Investigador Principal)	Carlos Andrés Torres Pinzón	4	39	USTA Sede Principal	$	2.221.888,5
Horas Nomina (Co-Investigadores)	Jhon Erik Navarrete Gómez	1	20	USTA Sede Principal	$	671.650
	Oscar Mauricio Gelvez Lizarazo	2	20	USTA Sede Principal	$	815.290

FINANCIACIÓN	RECURSO	DESCRIPCIÓN	Valor partida	Valor contrapartida (Externa)	Total ($)
RUBROS	Servicios Técnicos				$ 0
	Salidas de campo				$ 0
	Equipos	Estación de soldadura profesional: ✓ Temperatura Variable ✓ Extracción de gases Visor aumento X10 de escritorio.	$ 5'000.000		$ 5'000.000
	Materiales, insumos y software	Transistores de Potencia: IGBTs y MOSFETs. Diodo semiconductor de Potencia. Resistencias para montaje superficial de precisión. Condensadores para montaje superficial de precisión. Núcleos para inductores. Fabricación de Placas de Circuito Impreso (PCBs) ✓ 4 capas de fabricación ✓ Cobre con densidad de 4 Oz ✓ Normativa IPC2222. Reguladores de tensión eléctrica de media potencia.	$ 10'000.000		$ 10'000.000
BOLSAS	Papelería				$ 0
	Fotocopias				$ 0
	Material bibliográfico	Adquisición de los siguientes ejemplares: ✓ Battery Manufacturing and Electric and Hybrid Vehicles ✓ Electric and Hybrid Vehicles: Technologies, Modeling and Control a Mechatronic Approach	$ 1'000.000		$ 1'000.000
	Auxilio de transporte				$ 0
	Movilidad	**NIWeek 2020 (Austin, Texas, USA)** Offers the ultimate learning environment, featuring tools and knowledge you need to increase your proficiency for efficient test, design, and development.	$ 4'000.000		$ 4'000.000

	Publicaciones (Artículos, proceso editorial y traducción)	Publicación de los artículos en revista indexada.	$ 2'000.000		$ 2'000.000
TOTAL DEL PROYECTO:					$22'000.000

Referencias bibliográficas

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FINAL GRADE

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