Nº PROYECTO : 11110491  DURACIÓN : 3 años  AÑO ETAPA : 2013
TÍTULO PROYECTO : MAGNETIC COUPLED RECTIFIERS FOR LARGE CONTROLLED DC CURRENTS AND LOW VOLTAGE APPLICATIONS: DEVELOPING OF MODULAR TOPOLOGIES AND CONTROL SCHEMAS

DISCIPLINA PRINCIPAL : INGENIERIA ELECTRICA (INC POTENCIA)
GRUPO DE ESTUDIO : INGENIERIA 2
INVESTIGADOR(A) RESPONSABLE : JOHAN IGOR GUZMAN DIAZ
DIRECCIÓN : 
COMUNA : Concepcion
CIUDAD : Concepcion
REGIÓN : VIII REGION
### OBJETIVOS

Cumplimiento de los Objetivos planteados en la etapa final, o pendientes de cumplir. Recuerde que en esta sección debe referirse a objetivos desarrollados, NO listar actividades desarrolladas.

<table>
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<tr>
<th>Nº</th>
<th>OBJETIVOS</th>
<th>CUMPLIMIENTO</th>
<th>FUNDAMENTO</th>
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<tbody>
<tr>
<td>1</td>
<td>To design basic modules including rectifier, inverter, step down transformer and low voltage rectifier.</td>
<td>TOTAL</td>
<td>Converters, sensors, and drivers are designed, tested, redesigned, tested again and used on setups.</td>
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<tr>
<td>2</td>
<td>To build a SCR based rectifier to compare the proposed topology.</td>
<td>TOTAL</td>
<td>Rectifier was designed, built and tested. It was designed to manage 10kVA.</td>
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<tr>
<td>3</td>
<td>To build an experimental 10kW IPT rectifier using 3 modules rated at 5 kW each one.</td>
<td>TOTAL</td>
<td>Converter was built and tested. It uses three low power DSP (Texas Instrument M3C28), one for each module and one high power DSP (Texas Instrument 6713) to supervising the whole system.</td>
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<tr>
<td>4</td>
<td>To develop suitable gating patterns for the proposed topologies.</td>
<td>TOTAL</td>
<td>SHE, MSHE, DSHE, square shaped and predictive gating patterns were developed and tested.</td>
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<tr>
<td>5</td>
<td>To develop suitable control schemas for the proposed topologies.</td>
<td>TOTAL</td>
<td>PI based simple control schemes developed and implemented. Predictive based control schemes developed and implemented. Basic sequences for failure developed and tested.</td>
</tr>
<tr>
<td>6</td>
<td>To publish at three conference papers, one about topological issues and other two with control schemas</td>
<td>TOTAL</td>
<td>1-th Conference Paper Published: &quot;Comparison of CSI and VSI based modular rectifiers with magnetic AC coupling for large current and low voltage applications&quot; on IEEE/IECON 2012.</td>
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<td>2-th Conference Paper Published: &quot;Low Voltage and High current Rectifiers Using AC Magnetic Link: A Comparison of Main Topologies&quot; on ICEE/ICIT-2013</td>
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<td>3-th Conference Paper Accepted: &quot;Predictive Control of Modular Current Source Converters: a Comparison with PI controllers.” on IEEE-IECON-2014</td>
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Otro(s) aspecto(s) que Ud. considere importante(s) en la evaluación del cumplimiento de objetivos planteados en la propuesta original o en las modificaciones autorizadas por los Consejos.
RESULTS OBTAINED:

Main goal was to build a modular 10 kW prototype to validate the hypothesis considerations. 2013 work was focused on the building of complete systems and design of control strategies. As established on the specific schedule.

Specific goals

1. To design basic modules including rectifier, inverter, step down transformer and low voltage rectifier (100% complete):
   The equipment described were designed, built and tested. Rectifier, inverter module designed to be stacked to increase total current. It can commutate at 40 kHz in hard switching mode and up to 200 kHz at soft switching mode. Input is driven by fiber optic. Fan coolers at both sides kept temperature low. High frequency step down transformer designed for a wide frequency range (10kHz to 200 kHz) was built using list wire and ferrite cores. High frequency low voltage diode rectifier. A single way array was built for a 6 input topology.

Fig 1, Current Source Three-phase to single phase module. (a) front view, (b) back view.

Fig 2, High frequency 5 kVA Step down transformers.
2. **To build a SCR based rectifier to compare the proposed topology.** (100% accomplished)

Fig 4, Schema of double bridge four stars SCR based rectifier.

3. **To build an experimental 10kW IPT rectifier using 3 modules rated at 5 kW each one.**

**Fully accomplished,** The rectifier was designed, built and tested. That’s prototype will be used to compare the proposed topologies performance. It was designed to manage 10kVA using three modules of 5kVA.
4. **To develop suitable gating patterns for the proposed topologies.** (100 % accomplished)

Algorithm for SHE, Modular SHE (MSHE) and displaced SHE (SHE) were developed and tested. That year we are working on displaced SVM and predictive techniques to compare with.

2012 results, using SHE, MSHE and DSHE both 3-phase and 2-phase system was studied in terms of current quality, simplicity and reliability. There was developed a simple schema to change for the normal 3-phase operation in the inverters to the failure operating mode of 2-phase output.

(a) Comparing the behavior in failure operation of Modular SHE (MSHE) and Displaced SHE (DSHE) was found that DSHE have better performance than MSHE in both, balanced and unbalances operation. As depicted in the following figures.

The effects of asymmetries on the modulating indexes can easily be drawn for two cells in order to illustrate the phenomena. Fig. 6 and Fig. 7 show the THD for different modulating indexes using two converters and MSHE and DSHE techniques, respectively. The dotted line indicates symmetric modulating indexes (M1 = M2). MSHE presents regions where slight changes in the modulating indexes can produce considerable changes in THD. For example, operating at the modulating index [M1, M2] = [0.6, 0.6] and shifting to [0.6, 0.5] changes the THD from 42% to 89.8%. By contrast, the transitions for MSHE are moderate. In fact, for the conditions described above, the
THD changes from 41.2% to 44.9%. Thus, under normal operation of modular rectifiers, THD in
the DSHE technique is lower than THD in the MSHE technique. In brief, with modular rectifiers
operating normally, DSHE outperforms MSHE in terms of THD.

Also, suitable techniques to implement MSHE and DSHE on DSP based platforms were developed
and reported on an ISI Publication. The flux diagram is presented in the figures 8 and 9.

On the other hand, predictive approaches were developed and tested, generating good shaped
waveforms but increasing the average switching frequency more than twice respect to DSHE
approaches.

5. **To develop suitable control schemas for the proposed topologies.** (100 %
accomplished)

Control schemas for single cell, two cell and three cell are developed and tested.
Fig. 16. Block diagram for Modular MCC built up P voltage source modules.

Fig. 1, predictive control scheme.

PWMinverter

Input current controller

Single phase PWM Modulator

PWM Modulator

Output current controller

DC Voltage controller

Fig. 2, predictive control sampling frequency 50kHz, (a) input current $i_{r1}$ (b) input voltage scaled $v_{r1}$/2L (c) output current $i_{c1}$ (d) output current reference $i_{c1r}$ (e) input current for rectifier $i_{r1}$ (f) input current for rectifier 2 $i_{r2}$.

6. **To publish at three conference papers, one about topological issues and other two with control schemas.** (100% accomplished)

1-th Conference Paper Published: "Comparison of CSI and VSI based modular rectifiers with magnetic AC coupling for large current and low voltage applications" on IEEE/IECON 2012. Informet last year.

2-th Conference Paper Published: "Low Voltage and High current Rectifiers Using AC Magnetic Link: A Comparison of Main Topologies" on ICEE/ICIT-2013.


7. **To publish two article on ISI journals.** (50% accomplished.)


The paper "Digital Implementation of nonlinear control on IPT modular rectifiers" intended to be presented in the journal IEEE Transactions on Industrial Informatics is not complete yet. Still working on it.
1. Formation of human capital associated to the project:

   The student working on this project had learned to design electronics cards, to use DSP equipment’s, to specify components, to buy it and to build it. The specific work of each student is listed below:

   a. Daniel Diaz Besoain: He finished a memory on building of high frequency DC-LINK and programming of suitable code for DSP based platforms.
   b. Mario Gonzalez: He finished a memory on building of low frequency low voltage SCR based rectifiers and programming of suitable code for DSP based platforms.
   c. Cristobal Ramirez: He is currently working in optimizing the chrome plating of iron. In such memory he is using the converters as controlled DC sources of a mini chromium cell.

2. Formation of human capital not associated to the project.

   Reliable switches and current/voltage/power sensors and suitable loads and process were developed. These designs also were used in two non-related memories for students tutored by the principal investigator of this project:

   a. Mauricio Urra: He is working on plasma cannon using drivers and code developed in this project.
   b. Alex Martinez: He is working on plasma cannon using drivers and code developed in this project.
   c. Sebastian Arriagada: He is working on induction kitchens, using drivers and code developed in this project.
   d. Alvaro Donoso: He is working on improved sensors using optical links, starting at the sensors designed in project 1111-0491.
   e. Jose Miguel Ibarra: He is currently working in trespassing the code based protections of current source modules to hardware based protections to avoid failures due to DSP frozen.
PRODUCTOS

ARTÍCULOS
Para trabajos en Prensa/ Aceptados/Enviados adjunte copia de carta de aceptación o de recepción.

Sin información ingresada.

OTRAS PUBLICACIONES / PRODUCTOS

N° : 1
Autor (a)(es/as) : Eduardo Espinosa, Jose Espinoza, Roberto Ramirez, Jaime Rohten, Felipe Villarroel, Pedro Melin, Johan Guzman
Título (Idioma original) : A New Modulation Technique for 15-level Asymmetric Inverter Operating with Minimum THD
Tipo de publicación o producto : Otros
Especificar : IEEE conference records
ISBN :
Editor (es) (Libro o Capítulo de libros) :
Nombre de la editorial /Organización : IEEE conf. records. IECON2013 (Scopus)
País : AUSTRIA
Ciudad : Viena
Fecha : Octubre - 2013
Año : 2013
Vol. : 1
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Páginas : 6164-6169
Otras Fuentes de financiamiento, si las hay :
CONICYT / FONDECYT / 1110-794, CONICYT / FONDAP /1511-0019, CONICYT / FONDECYT / 1111-0491
Envía documento en papel : no
Archivo(s) Asociado(s) al artículo :
06700149.pdf

CONGRESOS

N° : 1
Autor (a)(es/as) : J. I. Guzman, M. A. Perez , P.E. Melin , J.R. Espinoza, C. R. Baier
Título (Idioma original) : Predictive Control of Modular Current Source Converters
Nombre del Congreso : iecon2014
País : ESTADOS UNIDOS DE AMERICA
Ciudad : texas
Fecha Inicio : 29/10/2014
Fecha Término : 01/11/2014
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<td>Daniel Diaz Besoain</td>
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<td>DISEÑO, CONSTRUCCION Y CONTROL DE UN CONVERTIDOR TIRISTORIZADO DOBLE ESTRELLA</td>
<td>Mario Gonzalez Rojas</td>
<td>johan guzman</td>
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| **N°** | 3 |
| **Título de Tesis** | DISEÑO, CONSTRUCCIÓN Y CONTROL DE UNA MINI-CELDA DE CROMADO ELECTROLÍTICO |
| **Nombre y Apellidos del(de la) Alumno(a)** | Cristobal Ramirez |
| **Nombre y Apellidos del(de la) Tutor(a)** | Johan Guzman |
| **Título Grado** | Pregrado |
| **Institución** | Universidad de Talca |
| **País** | CHILE |
| **Ciudad** | Curico |
| **Estado de Tesis** | En Ejecución |
| **Fecha Inicio** | 03/03/2014 |
| **Fecha Término** | 31/12/2014 |
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| **Archivo Asociado** | resumen_avance_memoria_cristobal_ramirez.pdf |