Introduction to Seoul Tech Power Electronics Lab

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Website (Korean): http://pefcl.seoultech.ac.kr

Website (English): http://eie.seoultech.ac.kr/en/intro/faculty
Geographical Location of Seoul Tech
Subway Lines in Seoul Metropolitan Area

Nearest subway station on Line 7 (5 minutes walk)
Overview of Seoul Tech

- Founded in **1910**

- Total number of students: **15,000**

- Undergraduate school: 6 colleges 26 departments

- Graduate school: 7 graduate schools
Campus Map

Land Size: 510,000 m² (124 Acres), the 5th largest campus in Seoul
Campus View
Why Seoul Tech?

• *Low tuition* in comparison with private universities (half ~ 2/3)

• Specialized in *Engineering* Colleges

• Ranked No.1 in the Graduates’ *employment rate* upon graduation (2013)

• Excellent *Scholarship* program

• Ranked *No.2 among National Universities* in Korea (2018)
# Guide for Schools

## Colleges

<table>
<thead>
<tr>
<th>College of Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>College of Information &amp; Communication Engineering</td>
</tr>
<tr>
<td>(48 faculty members)</td>
</tr>
<tr>
<td>- <em>Electrical &amp; Information Engineering</em></td>
</tr>
<tr>
<td>- Electronic &amp; IT Media Engineering</td>
</tr>
<tr>
<td>- Computer Science &amp; Engineering</td>
</tr>
<tr>
<td>College of Energy &amp; Biotechnology</td>
</tr>
<tr>
<td>College of Art &amp; Design</td>
</tr>
<tr>
<td>College of Humanities &amp; Social Sciences</td>
</tr>
<tr>
<td>College of Business &amp; Technology</td>
</tr>
</tbody>
</table>

## Graduate Schools

<table>
<thead>
<tr>
<th>1 General, 4 Professional</th>
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<tbody>
<tr>
<td>Graduate School</td>
</tr>
<tr>
<td>Professional Graduate School</td>
</tr>
<tr>
<td>- Railroad</td>
</tr>
<tr>
<td>- Public Policy &amp; Information Technology</td>
</tr>
<tr>
<td>- Energy &amp; Environment</td>
</tr>
<tr>
<td>- Nano IT Design Fusion</td>
</tr>
</tbody>
</table>
Global Programs for International Programs

Degree Program

- Undergraduate
- Graduate - Master, Combined Master/Ph.D, and Ph.D

Exchange Student Program (ESP)

- For students from the partner universities who wish to study at SeoulTech for 1 or 2 semesters

Visiting Program:
Seoul Tech International Season Semester (STISS)

- For partner universities’ students who want to study basic Korean language & culture

Korean Language & Culture Program (KLCP)

- For international students who want to study Korean language and culture intensively
On Campus Dormitory

**Sunglim Dormitory**

- Men:
  - Quad-room (4 person/room)
  - $150/month
- Women:
  - Double-room (2 person/room)
  - $200/month
- Bathroom inside room
- Shared kitchen / floor
- Shared washing machine

**International Dormitory**

- Single room ($400/month)
- Double room ($320/month)
- Bathroom inside room
- Kitchen inside room
- Washing machine inside room
Living @ Seoul Tech

Facilities
- Fitness center
- Table tennis room
- Café & Cafeteria
- Convenient store
- Running Track & Athletic Fields

Supports
- ISC(International Student Club)
  Supporting international students adjusting to life at Seoul Tech
- Airport Pick-up
- Cultural Tour
- Consulting service
Seoul Tech Power Electronics Lab

- 24 graduate students including 7 international students (13 PhD and 11 MS full-time students)
- Over 360 papers published in domestic and international journals and conferences
- 30 papers published in *IEEE Transactions on Power Electronics* (2010 ~ present)
- 31 domestic and international *patents* pending or registered
- Over 60 government & industry projects carried out (currently, 8 on-going projects)
# Publications

**Publications:** 373

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
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</thead>
<tbody>
<tr>
<td>SCI</td>
<td>44</td>
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<tr>
<td>Domestic journal</td>
<td>67</td>
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<tr>
<td>International conference</td>
<td>60</td>
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<tr>
<td>Domestic conference</td>
<td>202</td>
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**SCI Publications:** 44

<table>
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<tr>
<th>Journal</th>
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<tr>
<td>IEEE TPE</td>
<td>29</td>
</tr>
<tr>
<td>IEEE TIA</td>
<td>4</td>
</tr>
<tr>
<td>IEEE TIE</td>
<td>3</td>
</tr>
<tr>
<td>IET</td>
<td>2</td>
</tr>
<tr>
<td>JPE</td>
<td>2</td>
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<tr>
<td>IEEE TEC</td>
<td>1</td>
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<tr>
<td>Other</td>
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**Patents:** 26

<table>
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<tr>
<th>Type</th>
<th>Count</th>
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</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>23</td>
</tr>
<tr>
<td>International</td>
<td>3</td>
</tr>
</tbody>
</table>
Total number of citations: 3668 (Jan. 24, 2019)

h-index = 31
i−10 = 65
Major research areas

- **Fuel Cell and Photovoltaic Power Conversion Systems**
  - High power DC-DC converter (1kW~hundreds of kW)
  - Grid-connected Inverter

- **Power Converters for Electric Vehicles**
  - DC-DC converter, On Board Charger, Fast Charger

- **Energy Storage Systems**
  - Bidirectional DC-DC converter, Hybrid UPE-ESS system

- **DC Distribution and DC Microgrid**

- **Single-phase/Three-phase Power Factor Correction**
Sponsors for Seoul Tech Power Electronics Lab

- Hyundai
- Doosan Heavy Industries & Construction
- LG Innotek
- LG Electronics
- LS Industrial System
- Samsung SDI
- Samsung Electro-Mechanics
- Destin
- Signet
- Kaco
# Lab Equipment (amounts to $900,000)

<table>
<thead>
<tr>
<th>Type</th>
<th>Equipment</th>
<th>Specification</th>
<th>EA</th>
<th>Manufacture</th>
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<tbody>
<tr>
<td><strong>Sources</strong></td>
<td>3P Programmable AC Power Source</td>
<td>4.5kW</td>
<td>1</td>
<td>PACIFIC</td>
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<tr>
<td></td>
<td>Programmable DC Power Source</td>
<td>32kW (0–1000V)</td>
<td>1</td>
<td>REGATRON</td>
</tr>
<tr>
<td></td>
<td>Programmable DC Power Source</td>
<td>15kW (0–600V)</td>
<td>1</td>
<td>Sorensen</td>
</tr>
<tr>
<td></td>
<td>Programmable DC Power Source</td>
<td>26.6kW (0–80V)</td>
<td>1</td>
<td>MAGNA Power</td>
</tr>
<tr>
<td><strong>Loads</strong></td>
<td>AC Electronic Load</td>
<td>3kW</td>
<td>2</td>
<td>California Instrum.</td>
</tr>
<tr>
<td></td>
<td>DC Electronic Load</td>
<td>5.4kW, 500V</td>
<td>1</td>
<td>PRODIGIT</td>
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<tr>
<td></td>
<td>DC Electronic Load</td>
<td>3kW, 650V</td>
<td>1</td>
<td>Kikusui</td>
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<tr>
<td><strong>Measurement</strong></td>
<td>Multi-Channel Digital Oscilloscope</td>
<td>8ch, 1GHz</td>
<td>1</td>
<td>LeCroy</td>
</tr>
<tr>
<td></td>
<td>Multi-Channel Digital Oscilloscope</td>
<td>8ch, 500MHz</td>
<td>1</td>
<td>Yokogawa</td>
</tr>
<tr>
<td></td>
<td>High Function Digital Oscilloscope</td>
<td>4Ch, 500MHz</td>
<td>2</td>
<td>LeCroy</td>
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<tr>
<td></td>
<td>Power Analyzer</td>
<td>3P Volt, Amp, Harmonic Analysis</td>
<td>1</td>
<td>ZIMMER</td>
</tr>
<tr>
<td></td>
<td>Power Analyzer</td>
<td>Precision efficiency measurement</td>
<td>1</td>
<td>Yokogawa</td>
</tr>
<tr>
<td></td>
<td>Scopecorder</td>
<td>8ch/100MHz Scope, 16ch Thermo Couple</td>
<td>1</td>
<td>Yokogawa</td>
</tr>
<tr>
<td></td>
<td>High resolution thermal image camera</td>
<td>Range: -20 °C to +600 °C</td>
<td>1</td>
<td>Yokogawa</td>
</tr>
<tr>
<td></td>
<td>Logic Analyzer</td>
<td>16 channels</td>
<td>1</td>
<td>HP</td>
</tr>
<tr>
<td></td>
<td>LCR Meter</td>
<td>L, C, R measurement</td>
<td>1</td>
<td>HP</td>
</tr>
<tr>
<td></td>
<td>High current probe</td>
<td>150A</td>
<td>6</td>
<td>Yokogawa/LeCroy</td>
</tr>
<tr>
<td></td>
<td>High voltage probe</td>
<td>1000V</td>
<td>6</td>
<td>Yokogawa/LeCroy</td>
</tr>
<tr>
<td><strong>Softwares</strong></td>
<td>PSIM</td>
<td>Version(11.0)</td>
<td>10</td>
<td>Simtech</td>
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<tr>
<td></td>
<td>PADS</td>
<td>Version(1.2)</td>
<td>5</td>
<td>Mentor Graphics</td>
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<tr>
<td></td>
<td>PLECS</td>
<td>Version(4.0.5)</td>
<td>10</td>
<td>Research Centre</td>
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</table>
Experimental Set-up
Lab. Facilities
Current Lab. Members
Lab. Members with Alumni
Extra Activities
## Project related to electric vehicle (1/2)

### Fast Charger

<table>
<thead>
<tr>
<th>Title</th>
<th>Company</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of 25kW Bidirectional DC-DC Converter for Rapid Charger</td>
<td>Destin Power</td>
<td>2018.7 ~ 2019.6</td>
</tr>
<tr>
<td>Development of Next-Generation High-Voltage Supercharger for EV</td>
<td>Korean Research Foundation</td>
<td>2017.5 ~ 2020.4</td>
</tr>
<tr>
<td>Development of 50kW EV-NEV Combined Modular Rapid Charger</td>
<td>World Top Tech.</td>
<td>2014.3 ~ 2016.3</td>
</tr>
<tr>
<td>Development of High-Efficiency 50kW Rapid Charger for EV</td>
<td>Signet System</td>
<td>2013.2 ~ 2014.6</td>
</tr>
<tr>
<td>Developent of Optimum DC-DC Converter for Rapid Charger</td>
<td>LS Industries</td>
<td>2012.3 ~ 2012.8</td>
</tr>
<tr>
<td>100kW Rapid Charger Power Stack Development</td>
<td>LS Industries</td>
<td>2011.6 ~ 2011.12</td>
</tr>
</tbody>
</table>

### On-board Battery Charger

<table>
<thead>
<tr>
<th>Title</th>
<th>Company</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of Bi-directional Charger for V2G EV</td>
<td>IT Engineering</td>
<td>2015.12 ~ 2016.5</td>
</tr>
<tr>
<td>Development of Integrated Battery Charger for Environmentally Friendly Vehicles with Energy Storage Function</td>
<td>Korean Research Foundation</td>
<td>2014.5 ~ 2017.4</td>
</tr>
<tr>
<td>Development of 3.3kW Bi-directional charger for EV with V2G/V2H Function</td>
<td>Signet System</td>
<td>2013.2 ~ 2014.6</td>
</tr>
<tr>
<td>Development of High Efficiency and High Density DC-DC Converter for Environmentally Friendly Vehicles (HDC,OBC)</td>
<td>Korean Research Foundation</td>
<td>2010.5 ~ 2013.4</td>
</tr>
</tbody>
</table>
3.3kW Bidirectional Battery Charger for V2G/V2H

- Development of 3.3kW working prototype
- Operating modes: Charging/Vehicle-to-Grid/Vehicle-to-Home
- Proposed bidirectional resonant dc-dc converter achieves ZCS turn on & off
- Seamless transfer algorithm is realized

## Item Specification

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output power</td>
<td>3.3 kW</td>
</tr>
<tr>
<td>Grid voltage</td>
<td>110/220 V&lt;sub&gt;ac&lt;/sub&gt;</td>
</tr>
<tr>
<td>Battery voltage</td>
<td>250~410 V&lt;sub&gt;dc&lt;/sub&gt;</td>
</tr>
<tr>
<td>THD</td>
<td>&lt; 5%</td>
</tr>
<tr>
<td>Operation modes</td>
<td>Charging/V2G/V2H</td>
</tr>
</tbody>
</table>

### Operating Modes

- **Charging**
- **V2G**
- **V2H**

#### Charging Efficiency

- Measured by Yokogawa WT3000

#### Discharging Efficiency

- Mode change (Charging → V2H)
- Grid Fault
- Mode Transfer

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50kW Fast Charger for Electric Vehicles

- 50kW fast charger is consisted of five 10kW modules
- Each module consists of AC-DC converter and isolated DC-DC converters
- Current sharing control of 5 modules
- Proposed hybrid switching technique for the DC-DC converter results in peak efficiency of 98.7%

### Item Specification

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output power</td>
<td>50kW</td>
</tr>
<tr>
<td>Input voltage</td>
<td>3P 380V</td>
</tr>
<tr>
<td>Battery voltage</td>
<td>50~500 V</td>
</tr>
<tr>
<td>Power factor</td>
<td>&gt; 0.99</td>
</tr>
<tr>
<td>THD</td>
<td>&lt; 5%</td>
</tr>
<tr>
<td>Charging method</td>
<td>CC-CV</td>
</tr>
</tbody>
</table>

50kW fast charger is consisted of five 10kW modules. Each module consists of AC-DC converter and isolated DC-DC converters. Current sharing control of 5 modules. Proposed hybrid switching technique for the DC-DC converter results in peak efficiency of 98.7%.
### High Voltage DC-DC Converter

<table>
<thead>
<tr>
<th>Title</th>
<th>Company</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of High Efficiency and High Density DC-DC Converter for Environmentally Friendly Vehicles (HDC,OBC)</td>
<td>Korean Research Foundation</td>
<td>2010.5 ~ 2013.4</td>
</tr>
<tr>
<td>Development of Topology and Control Technology for HDC of Hybrid Vehicles</td>
<td>ADT</td>
<td>2006.12 ~ 2009.11</td>
</tr>
</tbody>
</table>

### Low Voltage DC-DC Converter

<table>
<thead>
<tr>
<th>Title</th>
<th>Company</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of GaN-based High-Frequency, High Power-Density LDC</td>
<td>Hyundai Motor</td>
<td>2018.7 ~ 2019.6</td>
</tr>
<tr>
<td>Development of 3.2kW Class DC-DC Converter for EV</td>
<td>LG InnoTek</td>
<td>2017.10 ~ 2018.8</td>
</tr>
<tr>
<td>Bidirectional DC-DC Converter for Power System</td>
<td>Samsung Electric</td>
<td>2013.3 ~ 2013.10</td>
</tr>
<tr>
<td>Development of 5kW bidirectional LDC for Military Tactical Vehicle</td>
<td>ADT</td>
<td>2012.3 ~ 2012.9</td>
</tr>
<tr>
<td>Development of Bi-directional DC-DC Converter for Fuel Cell Vehicle</td>
<td>Hyundai Motor</td>
<td>2007.6 ~ 2008.4</td>
</tr>
</tbody>
</table>
Development of GaN-based High-Frequency, High Power-Density LDC (Ongoing)

- Supported by: Hyundai Motor
- Period: 2018-7 ~ 2019-6
- Researcher: 김상진, 김형진, Adhis, 김규영, 김병우

Development contents:
- Topology selection for high power density (6kW/L)
- Development of GaN driver circuit for high switching frequency (>700kHz)
- Development of high frequency planar transformer
- Structure design and stack fabrication considering heat dissipation

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
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</thead>
<tbody>
<tr>
<td>Output power</td>
<td>1.8kW</td>
</tr>
<tr>
<td>Dimension (W<em>D</em>H)</td>
<td>150<em>80</em>25mm</td>
</tr>
<tr>
<td>Input voltage (HV)</td>
<td>200~310 V</td>
</tr>
<tr>
<td>Output voltage (LV)</td>
<td>Nominal 13.9V</td>
</tr>
<tr>
<td>Cooling system</td>
<td>Liquid (65°C, 8LPM)</td>
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</tbody>
</table>

< Planar transformer 3D model >

< EV converter system diagram >

< 1.8kW LDC 1st prototype 3D view >

< Core simulation results >
Development of DC-DC Converters for Fuel Cell Electric Vehicles (Ongoing)

- Supported by: Ministry of Industry
- Period: 2017-11 ~ 2021-7
- Researcher: 정현주, Hai, 김선주, 이동한

Development contents:
- Development of **114kW boost converter** for fuel-cell
- Development of **40kW bi-directional converter** for battery
- Application of SiC device and development of soft switching technology

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel-cell voltage</td>
<td>195~400V</td>
</tr>
<tr>
<td>Battery voltage</td>
<td>&gt; 200V</td>
</tr>
<tr>
<td>DC Link voltage</td>
<td>800V</td>
</tr>
<tr>
<td>Efficiency</td>
<td>96% peak</td>
</tr>
<tr>
<td>Power density</td>
<td>8.2 kW/L</td>
</tr>
<tr>
<td>Weight</td>
<td>18kg</td>
</tr>
</tbody>
</table>

Development of 3.2kW Class DC-DC Converter for EV
(Recently finished)

- Supported by: LG InnoTek
- Period: 2017-10 ~ 2018-8
- Researcher: 김병우, 김강산, Adhis, 조우식
- Development contents:
  - 3.2kW DC/DC converter circuit optimal design
  - Converter modeling and controller design
  - NXP MCU (MPC5741) digital control board design

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output power</td>
<td>3.2kW</td>
</tr>
<tr>
<td>Input voltage (HV)</td>
<td>250~450 V</td>
</tr>
<tr>
<td>Output voltage (LV)</td>
<td>Nominal 14V</td>
</tr>
<tr>
<td>Efficiency</td>
<td>94% peak</td>
</tr>
</tbody>
</table>

- 3.2kW prototype

< ISOP ACF Converter >

< Switch voltage & current >

< Load regulation >

< Line regulation >
DC-DC Converter for Mild Hybrid Electric Vehicles

- Supported by: Samsung Electro-Mechanics
- Development of 1.8 kW working prototype
- Bidirectional DC-DC converter for 12V-48V power nets
- Development of Digital Control Board using Automotive MCU
- 180A layout and thermal design
- High Efficiency over wide load range

Power Electronics & Fuel Cell Power Conditioning
High Step-up DC-DC Converter for 1.2kW, 16V Fuel Cells


- Supported by: Hyosung Heavy Industries
- Development of DC-DC converter prototype for production
  - Patented high step-up converter applied: 16V → 380V
  - ZVS turn ON of switches in all load range

![Diagram of DC-DC Converter](image)

- Measured by Yokogawa WT3000

```
92.7% @450W
96.3% @300W
93.7% @1140W
91.4% @1170W
```

![Efficiency Chart](image)
DC-DC Converter for Fuel Cell Vehicles

- Development of 2kW working prototype
- Proposed bidirectional isolated resonant dc-dc converter achieves ZCS turn on & off
- Theoretically zero output filter capacitance by resonant interleaved operation


![Diagram of DC-DC Converter for Fuel Cell Vehicles]

- Measured by Yokogawa WT3000

[Interleaved output current] [Ripple current of output capacitor]
## Project related to renewable energy and energy storage systems

<table>
<thead>
<tr>
<th>Title</th>
<th>Company</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of High Efficiency Isolated PV String Power Optimizer</td>
<td>Dass Tech</td>
<td>2019.1 ~ 2019.10</td>
</tr>
<tr>
<td>Droop Control of PV Inverters with Reduction of Common Mode Voltage</td>
<td>LG Electronics</td>
<td>2018.7 ~ 2019.7</td>
</tr>
<tr>
<td>Development of Multi-input Module Type PCS for Renewable Energy</td>
<td>Grida Energy</td>
<td>2017.9 ~ 2018.7</td>
</tr>
<tr>
<td>Development of 25kW Ultra Capacitor Charger</td>
<td>Destin Power</td>
<td>2016.7 ~ 2017.2</td>
</tr>
<tr>
<td>Development of DC-DC Converter for DC Nanogrid</td>
<td>Destin Power</td>
<td>2016.2 ~ 2016.12</td>
</tr>
<tr>
<td>Development of High-Voltage Bi-directional Converter Technology</td>
<td>LG Electronics</td>
<td>2015.4 ~ 2016.3</td>
</tr>
<tr>
<td>Development of 10kW PCS for ESS</td>
<td>Hansol Tech.</td>
<td>2014.10 ~ 2015.3</td>
</tr>
<tr>
<td>Development of Hybrid Energy Storage System for Demand Management</td>
<td>Industry/International Communication</td>
<td>2014.06 ~ 2017.05</td>
</tr>
<tr>
<td>Development of High Efficiency Bi-directional DC-DC Converter for BESS</td>
<td>Samsung SDI</td>
<td>2013.10 ~ 2014.03</td>
</tr>
<tr>
<td>Algorithm Development and Verification of PCS for MW Grid-type ESS</td>
<td>LS Industries</td>
<td>2013.10 ~ 2014.03</td>
</tr>
<tr>
<td>Development of High Efficiency and High Reliability Smart Home Energy</td>
<td>EESYS</td>
<td>2012.06 ~ 2014.05</td>
</tr>
<tr>
<td>Development of High Efficiency Bi-directional DC-DC Converter</td>
<td>Samsung SDI</td>
<td>2011.05 ~ 2011.11</td>
</tr>
<tr>
<td>Development of High Efficiency High Frequency Isolated Bi-directional DC-DC Converter Technology for ESS</td>
<td>LG Electronics</td>
<td>2011.05 ~ 2011.10</td>
</tr>
</tbody>
</table>
Development of Hybrid ESS for Demand Management with Emergency Power Function

- Supported by: Ministry of Commerce, Industry and Energy
- Period: 2014-6 ~ 2017-5
- Development contents:
  - Development of 250kW integrated ESS + UPS
  - Development of integrated control and rapid mode switching algorithm
  - TMS320F28377D integrated controller
  - Development of 3-level inverter technology
  - 5kW prototype and testing

### Item Specifications

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output power</td>
<td>250kW</td>
</tr>
<tr>
<td>Current THD</td>
<td>3% max</td>
</tr>
<tr>
<td>Mode switching time</td>
<td>&lt;4ms</td>
</tr>
<tr>
<td>Voltage fluctuation @ DC-AC</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Efficiency (round trip)</td>
<td>&gt;90%</td>
</tr>
</tbody>
</table>

<Configuration of Hybrid ESS>

<Battery charging mode>

<Emergency mode>

<Configuration of Hybrid ESS>
12kW Isolated Bidirectional Converter for Battery Formation

- Supported by: Samsung SDI
- Development of 12kW working prototype
- Bidirectional resonant converter for battery formation
- High frequency transformer with interleaved winding
- Low voltage high current power circuit and system layout design

**Item Specification**

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output power</td>
<td>12 kW</td>
</tr>
<tr>
<td>High side voltage</td>
<td>400 V</td>
</tr>
<tr>
<td>Low side voltage</td>
<td>12 V (max 1000A)</td>
</tr>
<tr>
<td>Battery current ripple</td>
<td>&lt; ±5%</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>32kHz</td>
</tr>
</tbody>
</table>

**Measured by Yokogawa WT3000**

- 96.3% Charging
- 96.5% Discharging
- 90.5% Charging
- 89.5% Discharging

- Diagram of power flow diagram
- Diagram of efficiency test results
- Notes: Supported by Samsung SDI
- Development of 12kW working prototype
- Bidirectional resonant converter for battery formation
- High frequency transformer with interleaved winding
- Low voltage high current power circuit and system layout design

**Power Electronics & Fuel Cell Power Conditioning Lab.**
Bidirectional DC-DC Converter for ESS

- Supported by: Samsung SDI
- Development of Bidirectional DC-DC converter for mass production
  → Patented bidirectional DC-DC converter applied to ESS
  → ZCS turn ON & OFF of switches
  → Peak efficiency of 96%

Switch Voltage & Current

Measured Efficiency

Peak Efficiency 96.1%
95% @2kW
3kW Hybrid ESS for Residential Use

- Hybrid generation system: Integrated PV PCS+ESS+UPS
- Isolated bidirectional DC-DC converter for battery charging
- LLC converter for PV MPPT
- Seamless mode change algorithm implemented

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output power</td>
<td>3 kW</td>
</tr>
<tr>
<td>Grid voltage</td>
<td>Single phase 220 V&lt;sub&gt;ac&lt;/sub&gt;</td>
</tr>
<tr>
<td>Battery voltage</td>
<td>128 ~ 162 V&lt;sub&gt;dc&lt;/sub&gt;</td>
</tr>
<tr>
<td>PV voltage</td>
<td>150 ~ 450 V&lt;sub&gt;dc&lt;/sub&gt;</td>
</tr>
<tr>
<td>THD</td>
<td>&lt; 5%</td>
</tr>
<tr>
<td>Main functions</td>
<td>CC-CV charging, seamless transfer</td>
</tr>
</tbody>
</table>

Measured by Yokogawa WT3000

Battery charging

Battery discharging

PV generation
20kW Bidirectional DC-DC converter for DC Nano-grid

- Supported by: Destin Power
- 20kW Bidirectional Converter for DC Nano-grid
- Peak efficiency of 98.9% using Full SiC IPM
- Implementation of DC Droop Control
- DSP control using TMS 320F28377D

< Proposed bidirectional converter>

< DC nano-grid system>

< 20kW Prototype>

- Development of core technologies of PCS for MCFC generation
  - Interleaved DC-DC converter design and current sharing control
  - Inverter control algorithm for Grid-tie and Stand alone modes
  - Islanding detection and seamless mode transfer
  - Reactive power control and LVRT
  - Master-slave control of parallel inverters

![Diagram of Power Conversion System for Megawatt MCFC Generation]

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**Power Electronics & Fuel Cell Power Conditioning Lab.**

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**[Megawatt Fuel Cell Power Plant]**
Awards

- KOFST Best Paper Award, 2009
- KIPE Outstanding Technical Achievement Award, 2003
- KIPE Outstanding Academic Achievement Award, 2002

Received at International competition sponsored by *U.S. Department of Energy* and *IEEE PELS*

- 1st place, 2003 Future Energy Challenge (Topic: Fuel cell inverter)
- 2nd place, 2005 Future Energy Challenge (Topic: Grid-connected inverter)
- 2nd place, 2011 Future Energy Challenge (Topic: Battery charger)

www.energychallenge.org !!!
2003 Future Energy Challenge Competition

- **Sponsor**: US DoE and IEEE
- **Topic**: Fuel Cell Inverter
- **Participants**
  - Seoul Tech
    - Grand Prize ($30,000)
  - Virginia Tech
    - Presentation Award ($5,000)
  - Texas A&M University
  - University of Wisconsin
  - West Virginia University
  - Michigan State University
  - Ohio State University
  - University of Missouri, Rolla
  - Colorado School of Mines
  - Drexel University
  - University of Akron
  - University of Central Florida

- DSP control
- Soft-switching achieved
- Design of high frequency transformer
- Packaging and system integration
2005 Future Energy Challenge Competition

- Sponsor: US DoE and IEEE
- Topic: Utility Interactive Inverter
- Participants
  - Monash University (Australila) -- 1st Place
  - Seoul Tech (Korea) -- 2nd Place
  - University of Illinois (USA) -- 3rd Place
  - University of Wisconsin (USA)
  - Texas A&M University (USA)
  - Aachen University (Germany)
  - Michigan State University (Germany)
  - University of Central Florida (Germany)
  - Federal Univ of Mato Grosso do Sul (Brazil)
  - Bangladesh University (Bangladesh)
  - Federal University (Brazil)
  - Krishna Institute (India)
  - Memorial University (Canada)
  - Nanjing University (China)
  - State University of Campinas (Brazil)

- Grid tie & island modes of operation
- Automatic mode transfer
- LCL filter design
- DSP control

Additional text:

Aim of the Future Energy Challenge Competition:

- Grid tie & island modes of operation
- Automatic mode transfer
- LCL filter design
- DSP control

Sponsor: US DoE and IEEE
Topic: Utility Interactive Inverter
Participants:
- Monash University (Australila) -- 1st Place
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- Bangladesh University (Bangladesh)
- Federal University (Brazil)
- Krishna Institute (India)
- Memorial University (Canada)
- Nanjing University (China)
- State University of Campinas (Brazil)
2011 Future Energy Challenge Competition

- Sponsor: IEEE Power Electronics Society
- Topic: **Battery Charger** for Renewable energy & Electric vehicles
- Participants
  - Virginia Tech (USA) ------------------- 1st Place
  - Seoul Tech (Korea) ------------------- 2nd Place
  - University of Kassel (Germany) ---- - 3rd Place
  - University of Connecticut (USA)
  - National Taiwan Univ of Science and Tech (Taiwan)
  - Huazhong Univ of Science & Technology (China)
  - Indian Institute of Technology (India)

![Battery Charger Diagram]

- 3kW Battery charger for electric vehicles
  - Optimized design of Isolated DC-DC converter
  - Soft-switching achieved in the whole operating range
- CC-CV, CP-CV battery charge
- CAN communication and DSP control

![Efficiency Graph]

- Measured by Yokogawa WT3000


M. Kwon, S. Choi, " Control Scheme for Autonomous and Seamless Mode Switching of Bidirectional DC-DC Converters in a DC Microgrid", *IEEE Transactions on Power Electronics*, June 2018


S. Kim, M. Kwon, S. Choi, " Operation and control strategy of a New hybrid ESS-UPS system", IEEE Transactions on Power Electronics, *IEEE Transactions on Power Electronics*, June 2018


International Journal Publication (3/4)


Sewan Choi

Education
B.S. in Electronic Engineering, *Inha University* in 1985
M.S. in Electrical Engineering, *Texas A&M University* in 1992
Ph.D. in Electrical Engineering, *Texas A&M University* in 1995

Experience
1985 - 1990, Research Engineer, *Daewoo Heavy Industries*
1996 - 1997, Principal Research Engineer, *Samsung Electro-Mechanics Co*
1997 - present, Professor, Dept of Electrical & Information Eng, *Seoul Nat’l Univ. of Science and Technology*

Activities
2004 - present, Executive Board Member, Vice President(2017-2018), *Korean Institute of Power Electronics*
2004 - 2008, Consulting Professor, *Hyundai Motor Company*
2006 - present, Associate Editor, *IEEE Transactions on Power Electronics*
2010 - 2015, Associate Editor, *IEEE Transactions on Industry Applications*
2015 - present, Associate Editor, *IEEE Journal of Emerging & Selected Topics in Power Electronics*
2019 - present, Seoul Chapter Chair, *IEEE Power Electronics Society*
2019 - present, Fellow Member, *IEEE*

Research interests
Power conversion technologies for renewable energy systems and energy storage systems
DC-DC converters and battery chargers for electric vehicles
Full financial support for tuition and living expense is available to all admitted Ph.D or Master combined Ph.D students.

For information on the financial support, please contact directly to Prof. Sewan Choi at schoi@seoultech.ac.kr