Project Updates: Power Technologies

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## Project Updates: Power Technologies

<table>
<thead>
<tr>
<th>Project Code</th>
<th>Title</th>
<th>Principal Investigators</th>
<th>Focus Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR-15-03</td>
<td>Mobile Power Substation</td>
<td>Juan Balda, Thouhidul Islam</td>
<td>Solid State Transformer &amp; Mobile Power Substation</td>
</tr>
<tr>
<td>GR-15-05</td>
<td>PMU Role in Evaluating PV Generation Impact on Transmission Grid</td>
<td>Andrea Benigni, Roy McCann</td>
<td>Distributed Energy And Microgrid Management</td>
</tr>
<tr>
<td>NSF-15-06</td>
<td>Physics-Based Compact Modeling of GaN Devices for Advanced Power Electronics</td>
<td>Alan Mantooth, Ram Kotecha</td>
<td>Grid tied Power Electronic Modules</td>
</tr>
</tbody>
</table>
### Optimization and Reliability Assessment of Power Electronic Modules

**GR 15-01**

<table>
<thead>
<tr>
<th>PROJECT OBJECTIVES</th>
<th>PLANS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Paralleling of several Si/SiC based semiconductor devices to increase current handling capability of power modules</td>
<td>• Realize wire bondless power modules with paralleled semiconductor devices</td>
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<td>• Stacking of several power modules with paralleled devices in series combination to achieve high voltage</td>
<td>• Realize the proposed module level stack to achieve series connection</td>
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<tr>
<td>• Investigate the reliability of the paralleled and stacked power modules in terms of electrical, thermal, mechanical and material standpoint.</td>
<td>• Electrically characterize the module level stack</td>
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<td>• Improved analytical design methodology by simulation techniques</td>
<td>• Perform passivation reliability assessment (HTRB, H3TRB, Thermal Shocks) for high voltage power devices</td>
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<td>• Investigate optimal passivation solution for high voltage power devices through reliability test</td>
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<thead>
<tr>
<th>PROGRESS SINCE LAST REVIEW</th>
<th>SCHEDULE/EXPENSES VS. PLAN</th>
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</thead>
<tbody>
<tr>
<td>• Fabricated a LTCC based interposer with embedded spring loaded mechanical contacts</td>
<td>• Integration of different piece parts of the power module with interposer is on-going</td>
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<tr>
<td>• Perform electrical, thermal, and mechanical simulations to study the power module</td>
<td>• Passivation reliability study is on going and on schedule</td>
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<tr>
<td>• Passivation reliability tests are being concurrently performed</td>
<td>• The project is within the IAB budgeted amount</td>
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<tr>
<td>• Developed a simulation methodology for predicting EMI/EMC in power modules and performed hardware verification of the proposed simulation methodology</td>
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<tr>
<td>• Presented a paper at IMAPS CICMT, April 2016, a journal paper on EMI is accepted by the IEEE Journal of Emerging and Selected Topics in Power Electronics</td>
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</tbody>
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Objectives/Goals of the Project

- Evaluate potential designs for interfacing two medium-voltage distribution systems operating under emergency conditions using a mobile power substation that is light weight (to be transported in a single truck) and cost effective.

Plans

- Comparison of hard-switching MMC- and FCC-based topologies
- Analysis of soft-switching modular DAB-based SST topology
- Simulation of hard-switching topology
- Simulation of the DAB-based SST
- Building a scaled-down prototype
- Technology transfer to industry

Progress Since Last Review

- MMC and FCC topologies were analyzed
  - Devices, capacitors and inductors were chosen
  - Theoretical efficiencies calculated
  - MF transformer designed
  - Device thermal analysis conducted
- Initial design of the modular SST was formulated

Budget/Expenses vs. Plan

- Budget: $68,630
- Expenses: $41,579

Future Activities

- Simulation of MMC topology
- Design of DAB-based SST
- Simulation of DAB-based SST
- Proposed topology for scaled-down prototype
PMU-Based Wide Area Control of PV Generation (GR15-05)

• Objectives/Goals of Project
  • Pilot project to evaluate benefit and costs of synchrophasor systems for power electronics microgrid connected devices for planning and control functions.

• Plans
  ▪ UA: PMU pilot set-up configuration in June-July 2016 (Ozarks Electric and SEL) at 1.0 MW solar installation.
  ▪ UA: Data collection July-Dec 2016.
  ▪ USC: Project concluded
  ▪ No further project continuations or funding is requested.
  ▪ Future work for separately funded projects in synchrophasor controls of PV inverters.

• Progress Since Last Review
  • USC: A prototype of a PV inverter controller with PMU capability has been developed.
  • USC: The use of model reduction techniques to ensure state estimation observability even with a reduced number of measurements available has been evaluated.
  • UA: Synchrophasor data recording and analysis capability for 1 MW PV array.

• Schedule/Expenses vs. Plan
  ▪ UA: No expenses (donations) during Jan – May 2016.
  ▪ UA: Student hourly pay summer 2016: Per budget plan ($6000 May 15 – Aug 15 2016).
  ▪ USC: Two MS visiting students supported by scholarships, 2 weeks of faculty time ($6000 May 15 – Aug 15 2016)
**Objectives/Goals of Project**
- To develop a physics-based analytical model of GaN power devices for circuit simulations
- To implement the model using MAST and Verilog A
- To characterize the state-of-the-art GaN devices
- To validate the model against the static and dynamic device characteristics

**Plans**
- To develop a physics-based CV model of GaN power devices
- To implement the DC and CV model using MAST and Verilog A
- To perform dynamic characterization of GaN devices using a clamped inductive load
- To develop power electronic circuits for high speed GaN switches

**Progress Since Last Review**
- Characterization of EPC2021 eGaNFET transistor for DC and CV characteristics
- Analyzed the GaN Power HEMT behavior using TCAD Sentaurus
- Developed a DC model for the device using drift-diffusion model for carrier transport

**NSF Grant for 3 years since Aug 2015**
- Model formulation
- Device characterization
- Model implementation
- Model validation
- Development of high-speed power converter circuits