PV inverter control to sustain high quality of service

**Objectives/Goals of Project**
- Develop a two-stage hierarchical control structure where:
  - A top-level day-ahead control optimizes energy losses and voltage deviations (1st Jan 2015 – 31st December 2015)
  - A fast on-line control compensates for generation and load variability (1st Jan 2016 – 31st December 2016)

**Plans**
- Finalization of cooperative decentralized control
- Evaluation with different communication bandwidth limits and power system test cases
- Prepare papers for ISGT and for Transactions on Smart Grids on real time control

**Progress Since Last Review**
- Real-time tests for the on-line control
- First comparison of real-time approaches
- Journal paper “Coordinated Optimal Scheduling in Distribution Grids with PV Penetration” submitted

**Schedule/Expenses vs. Plan**
- Project has been delayed due to reduced manpower during 2016
- A no-additional-cost extension of 6 months is requested
PV inverter control to sustain high quality of service

- A six month no cost extension is requested
- In this six month we will:
  - Finalize the real time control
  - Submit a journal paper on the on-line real time control
- The founds will cover
  - 1 Phd student (Yan Chen)
  - 2 Undergraduate (Briana Luckey, Jerrod Wigmore)
### Objectives/Goals of Project
- Evaluate and verify designs of microgrid and its central converters in an unique high power testbed (NCREPT). High power rating, in terms of MVA, of converters make the microgrid stability issue more challenging. More sophisticated hardware design and control algorithms are required.

### Plans
- Increase power to at least 500 kVA.
- Validation of high power islanded mode (with VVVF).
- Technology transfer to industry.

### Progress Since Last Review
- Build a prototype of 1 MVA ac-dc converter for verifying new microgrid converter design and control algorithm.
- Design and validate high power LCL filter by using FeSi power core variable inductor (test up to 200 kVA now).
- Propose and validate a new soft-start control algorithm of microgrid ac-dc rectifier for mitigating inrush current.

### Schedule/Expenses vs. Plan
- Test maximum power at Jan 2017
- Finish project and documentation $40,000 has been approved Nov 2015
GR-16-03 Prototyping Tri-window Compensator

- **Objectives/Goals of Project**
  - First deliverable was the cost analysis of a Static VAR Compensator, capable of compensating the reactive and unbalance power of non-periodic loads.
  - Second deliverable was the modification of the tri-window compensator to be feasible for practical implementation.
  - Third deliverable is the implementation of the proposed tri-window compensator into an NI real-time controller.
  - Fourth deliverable is the design and implementation of the non-periodic load model emulator utilizing a controller-in-the-loop structure.
  - Fifth deliverable is the demonstration of the proposed technique capability in performing the compensation of the non-periodic load using a controller-in-the-loop structure.

- **Plans**

  ![Task Progress Chart]

  - **Task Completion Status**
    - Task: Likelihood survey
      - Completion: 1
    - Task: Evaluation and comparison of the existing techniques
      - Completion: 2
    - Task: Simulation of a promising compensation approaches
      - Completion: 3
    - Task: Compensation Technical Development
      - Study of the characteristics of the non-periodic current
        - Completion: 4
      - Design of the basic scheme of a tri-window compensator
        - Completion: 1
      - Design of the reactive, fast, and slow compensator
        - Completion: 2
      - Definition of new power quality criteria
        - Completion: 3
      - Design specification for the slow compensator
        - Completion: 4
      - Development of fuzzy algorithm for the slow compensator
        - Completion: 1
      - Method evaluation using real-world data
        - Completion: 2
    - Task: Prototype Development
      - Study, cost analysis, and selection of SVC configuration
        - Completion: 3
      - Hardware feasibility study for the implementation of the fast compensator
        - Completion: 4
      - Software feasibility study for the implementation of the fast compensator and refinement of the fast compensator
        - Completion: 1
      - Implementation of controller-in-the-loop to test the proposed compensator
        - Completion: 2
      - Demonstration
        - Completion: 3

- **Progress Since Last Review**
  - Refinement of the compensator to be feasible for practical implementation,
  - Implementation of an adaptive fast compensator that allows sharing of the bandwidth and power rating between the fast and the slow compensator,
  - Real-time implementation of the proposed compensator using controller-in-the-loop structure.

- **Schedule/Expenses vs. Plan**
  - 30k budget approved at Nov meeting
  - 20k spent to date on graduate student stipend and tuition
  - 2K spent on prototyping parts
  - 5k needed for graduate student stipend to finish the project
  - 3k for travel expenses

Note: GR-16-03 began in 2016 based on earlier work
Objectives/Goals of Project
- To develop a cost-effective high power real-time PV simulator, which can reproduce the PV behavior at the ripple frequency.
- Use both computer-based simulation and hardware-in-the-loop simulation to validate the effectiveness of the proposed PV simulator.

Plans
- Develop a 1-KW hardware test setup for the proposed power stage;
- Implement control algorithms for both rectifier and buck converter in TI DSP;
- Validate the effectiveness of the proposed PV simulator using experiment studies.

Progress Since Last Review
- A 3-phase interleaved dc-dc converter (power-stage) was developed;
- A high bandwidth sliding mode controller (SMC) was designed;
- The SMC was implemented in TI DSP
- Validated the proposed design using both Matlab Simulink and hardware-in-the-loop (HIL) simulation studies.

Schedule/Expenses vs. Plan
- Start date: 01/01/2016.
- Original completion date: 12/31/2016.
- Request no-cost extension to 06/30/2017 to complete hardware demo
- PI: Dr. Yue Zhao
- Overall budget: $ 20,000
Project Plan

- Total Project Budget $20,000 (01/01-12/31/2016)
- Current available funds: $11083.70
- Request **no-cost extension** to **06/30/2017**
- Hardware-in-the-loop (HIL) simulation studies have been completed, hardware experimental studies are proposed to be performed during the extended period, which will include:
  - Development of 1-kW hardware test setup for the proposed PV simulator power stage;
  - Implementation of control algorithms for both rectifier and buck converter in TI DSP;
  - Validation and verification using experiment studies;
  - 1 student will be supported for 6 months to complete the proposed work.
**Objectives/Goals of Project**
- This project feeds into a larger project to incorporate a DC microgrid into a cluster of homes within an underserved neighborhood in Milwaukee.
- The focus of this project is to develop a safe and reliable method for DC distribution and protection.
- The goal is to verify the effectiveness of a radial architecture using autonomously coordinating solid state circuit breakers.

**Plans**
- Build 350V laboratory platform to prove out normally “On” SiC JFET protective strategy (1-5 months).
- Develop a bidirectional AC/DC converter and determine the optimal topology (1-3 months).
- Develop new home power panel and POL converters (4-8 months).
- Integrate the system in a laboratory environment and perform fault characterization (8-12 months).

**Progress Since Last Review**
- Completed AC/DC topological study comparing current limiting (current source converter) and non-current limiting (voltage source converter) from the standpoints of power quality and EMC in a residential application.
- Developed an LT Spice model for the SiC JFET based Solid State Circuit Breaker (SSCB) and validated model against prior experimental work.
- Developed approach for tuning time-trip characteristics of SSCB.
- Obtained one SiC JFET SSCB prototype for fault characterization tests and bill of material so that additional units can be built and tested in a cascaded structure.
- Procured 12V, 24V and 48V supplies for the purpose of building laboratory test system.
- Began work with an engineering firm (GRAEF electrical) and an electrical contract to start design of the system for the target homes.

**Schedule/Expenses vs. Plan**
- Effective project start date moved to May 1, 2016 due to funding delays.
- AC/DC Converter topology study completed.
- Testing of SSCB on track to be complete by end of year.
- Coordination testing of SSCB on track to be complete in February.
- Final laboratory system integration has begun and on track to be complete in 7 months.
- Expenses so far:
  - Direct Salaries: $11,444
  - Fringe Benefits: $4,234
  - Supplies: $4,811
  - Grad Students $28,215
- **Total Expenditure: $35,508 out of $40,000**
GR-15-04

FEASIBILITY OF TIME-FREQUENCY ANALYSIS BUILT INTO POWER CONVERTERS FOR CABLE HEALTH MONITORING (GR-15-04)

• **Goal of Project**
The goal is to establish the feasibility of reflectometry analysis built into power converters for cable health monitoring.

• **Objectives:**
  - Investigate the feasibility of this approach
  - Define the required modifications to an existing power converter

• **Activities:**
  - Applied different signal processing methods to find the best performing one.
  - Investigated other type of faults beside hard faults, e.g. using a parallel fault to model insulation deterioration

• **Conclusions:**
  - The signal produced by injection circuit can be used for TDR purposes and experimental results have shown the feasibility of proposed setup.
  - The method works well with relatively large reflections which reduce the effect of noise.
  - In order to detect soft faults that have subtle effects on reflection waveforms, it is necessary to deal with and reduce measurement noise (future work)

• **Research outputs:**
  - **Hardware:** injection circuit capable of adding to an existing power converter
  - **Algorithm:** using TDR and signal processing method to detect the faults

• **Publication:**
  - **Thesis:** Cable health monitoring system built into power converter using time domain reflectometry