Testbed for Mitigation of Power Fluctuation on Micro-Grid

Presented by Xin Zhao
UC San Diego
April 1, 2015
The project was sponsored by the California Energy Commission.

UC San Diego Team

- Xin Zhao  
  System Identification and Control Laboratory, UC San Diego
- Raymond de Callafon  
  System Identification and Control Laboratory, UC San Diego
- Maurice van de Ven  
  Eindhoven University of Technology
- William Torre  
  Center for Energy Research, UC San Diego
- Chuck Wells  
  Center for Excellence, OSIsoft

OCC Team

- Greg Smedley  
  One-Cycle Control Inc.
- Tong Chen  
  One-Cycle Control Inc.
Outline

• Introduction

• Testbed for mitigation of power fluctuation
  – Overview
  – “Portable” cabinet
  – Controller

• Preliminary tests on the testbed

• Future work
Introduction
Motivation for mitigation of power fluctuation

- Power fluctuation occurs intermittently on micro-grid.
- Conventional generation tends to stabilize and maintain synchronous operation of the system by the inertia in the form of spinning rotational mass.
- As more renewable energy generation is added to the utility grid, it could result in instability and poorly damped oscillations in AC frequency and power on micro-grid.
Introduction

Objectives of building a testbed

- Simulate a power fluctuation
  - Motor load
  - Oscillatory circuitry

- Detection of instantaneous fluctuations
  - Phasor Measurement Unit (PMU)
  - Instantaneous power sensor

- Verification of data-based dynamic modeling (system identification) techniques

- Damping controller design and implementation
  - Embedded devices

- Capability of real-time control of an inverter
  - An inverter with real-time active/reactive power control
Testbed
Inverter with real-time control

Controller with implementation of instantaneous power calculation and damping control

Oscillatory circuitry acting as a power fluctuation
“Portable” cabinet

- **Grid-Tied Inverter**
- **Controller Cabin**
- **Oscillatory R-L-C circuitry**
Controller

Manufacturer: National Instruments
Model: NI myRIO-1900

- Processor: Xilinx Z-7010 (Duo Core, 667MHz)
- Memory: (ROM) 256MB (DDR3) 512MB
- Wireless: IEEE 802.11 b,g,n
- Analog Input: 12 bits – 500 kS/s
- Analog Output: 12 bits – 345 kS/s
Preliminary Tests
Test of simulating power fluctuation

• For safety consideration, a programmable DC power supply is installed for testing.

• The power fluctuation generated by the oscillatory circuitry is measured and modeled as follows: \( f_n \approx 5\text{Hz} \)
Preliminary Tests

Four-quadrant grid-tied inverter (GTI)

Manufacturer: One-Cycle Control (OCC)
Model: GTI3100A6208/3652IR-PQ

- Max. Power: 36kW
- AC Voltage Range: 208V ± 10%
- Rated DC Voltage: 365VDC
- Max. AC/DC Current: 100Arms / 100A
- Weight: 65lb
- Size: 23in × 17.5in × 5.25in
Preliminary Tests

**Capability test of real-time active/reactive power control**

- Dynamic response of the OCC-GTI is tested with a step control input.
- The OCC-GTI is capable to be controlled in real time.
Verification of data-based system identification on the GTI output

- Based on the measured data obtained by previous tests, a low-order model built within Prediction Error (PE) framework is capable to capture the dynamics.
Verification of data-based system identification on the disturbance

- Dynamic response of the oscillatory circuitry is tested.

- A low-order model built by Step-Based Realization (SBR) method is capable to capture the dynamics well.
Damping control algorithm design and implementation

- A preliminary damping control algorithm is designed based on modeling of the system described previously.

- The control algorithm is implemented in the controller.
Conclusions

- The oscillatory circuitry in the testbed is able to simulate a power fluctuation.

- The grid-tied inverter provided by One-Cycle Control is capable to be controlled in real time.

- The controller is able to process the instantaneous power calculation and real-time control.

- The designed control algorithm is able to dampen the oscillation generated by the oscillatory circuitry.
Future Work
Future Work

Large-scale integration tests

- Integration with Phasor Measurement Unit (PMU)
- Integration with photovoltaic (PV) systems
- Large-scale tests on UCSD micro-grid
Thank you