Advanced Distribution Automation:
In-Line Power Regulator (IPR)
Project Plan

In coordination with,

PREPARED EXCLUSIVELY FOR:

The IIT Smart Grid Lab Partners

PREPARED:

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Project Details

Project Name:	Advanced Distribution Automation – Intelligent Power Regulator (IPR)
Project Delivery Owner:	John Shen
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Version Control

Version	Date	Author	Change Description
1.0	11/7/2014	Mel Gehrs	Initial document creation
1.1	11/13/2014	John Shen	First round edits
1.2	11/23/2014	John Shen	Incorporate review notes from team
2.0	12/10/2014	John Shen	Incorporated comments from Gridco/Mel

PROJECT BACKGROUND

Little has changed in the last 50 years in the management and control of a utility's distribution grid. The concepts of centralized power stations and voltage control on the primary feeders are ingrained in the equipment and control schemes. Unfortunately the customer side of the distribution grid has changed substantially with the installation of distributed generation (solar, wind, fuel cells, batteries, gas turbines), non-linear switching power supplies (LED streetlights, computers, electric vehicles), PHEV charging stations, battery storage and the ability to island (e.g. Microgrids) a portion of the grid for reliability reasons. These trends are causing flows to become less predictable and increasingly rendering existing methods of distribution grid management and control incapable of regulating power to within prescribed service assurance standards. Add to this dynamic an increasing focus on the customers, their usage, energy efficiency, power quality, access to detailed interval data and it becomes apparent that the distribution grid requires a new paradigm of distributed local control.

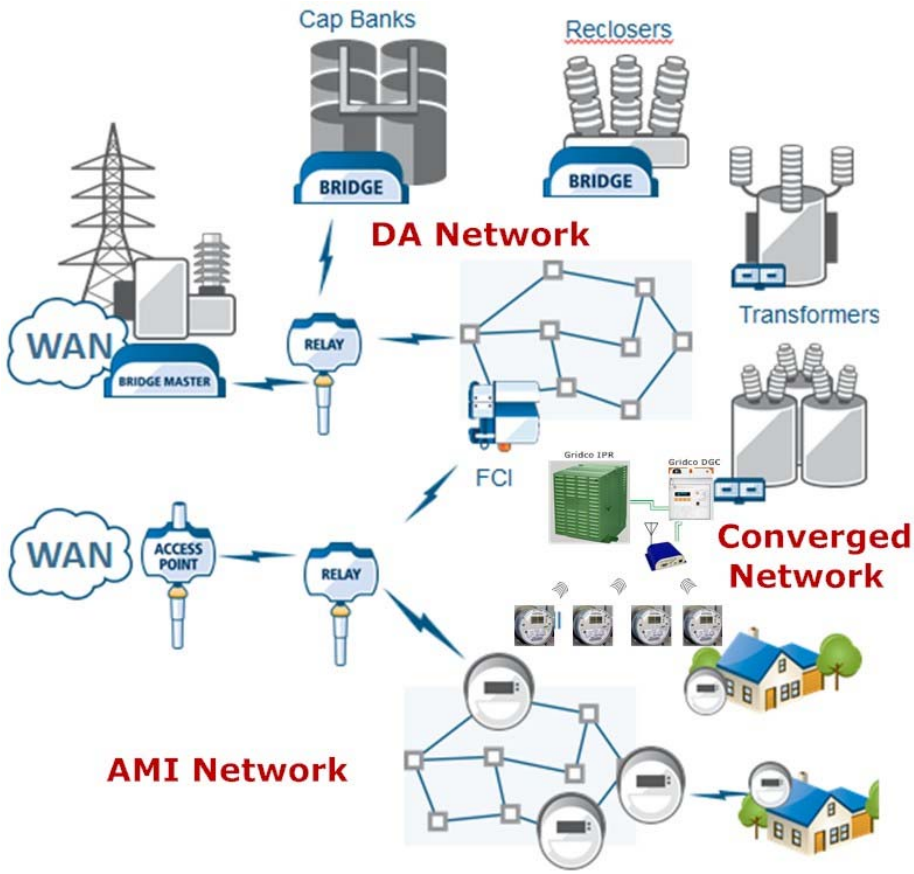
Gridco Systems has designed a device to fit this paradigm. It implements a solid state buck/boost inline power regulator (IPR) that can locally control voltage, power factor and harmonic suppression for a standard 50KVA distribution transformer. This device aims to actively and dynamically control the distribution grid. The goal of this project is to demonstrate the capability of the Gridco Systems IPR working in conjunction with SSN Smart Meters and Bridges to optimally control the local grid in spite of the variation imposed by the increasing customer load complexities.

Desired Outcomes

While there are a variety of applications for distributed local grid control, we will start by testing and demonstrating two use cases that are relevant to the utility business: Conservation Voltage Reduction (CVR) and detection of technical and non-technical losses. If tests are successful, this will demonstrate not only the Gridco Systems product but also the concept of distributed local control for the distribution grid using SSN Smart Meters and Bridges. Other applications include distributed power factor control and distributed harmonic mitigation, which will be tested in later phases of the project. These use-cases have not yet been demonstrated using this combination of technologies.

This project is also an opportunity to explore the concept of convergence. Much has been written and discussed about the potential for a converged AMI and DA network. Most of these discussions have centered around shared infrastructure to reduce cost of equipment and deployment. However, as you can see from Figure 1, this project is a completely new type of convergence based on LOCAL information sharing between smart meters (AMI) and DA devices to improve voltage control and identify losses. The Silver Spring radio with its frequency hopping and 83 channels of simultaneous communications between devices is uniquely designed to support this information sharing by localizing the data traffic to the backyard devices that form the local control grid. Increasingly, advanced DA grid applications will require a single converged AMI/DA communications platform.

Figure 1:



The project team will leverage IIT's CSMART lab to provide facilities and personnel to test the capabilities of the Gridco Systems IPR and SSN Smart meters/Bridges working together. In addition, the CSMART PI Historian will be used to record and analyze the results from the various tests and configuration options.

Primary Objectives

- Demonstrate distributed voltage control
- Demonstrate distributed CVR capability
- Demonstrate real time Technical (TL) and Non-Technical Loss calculations

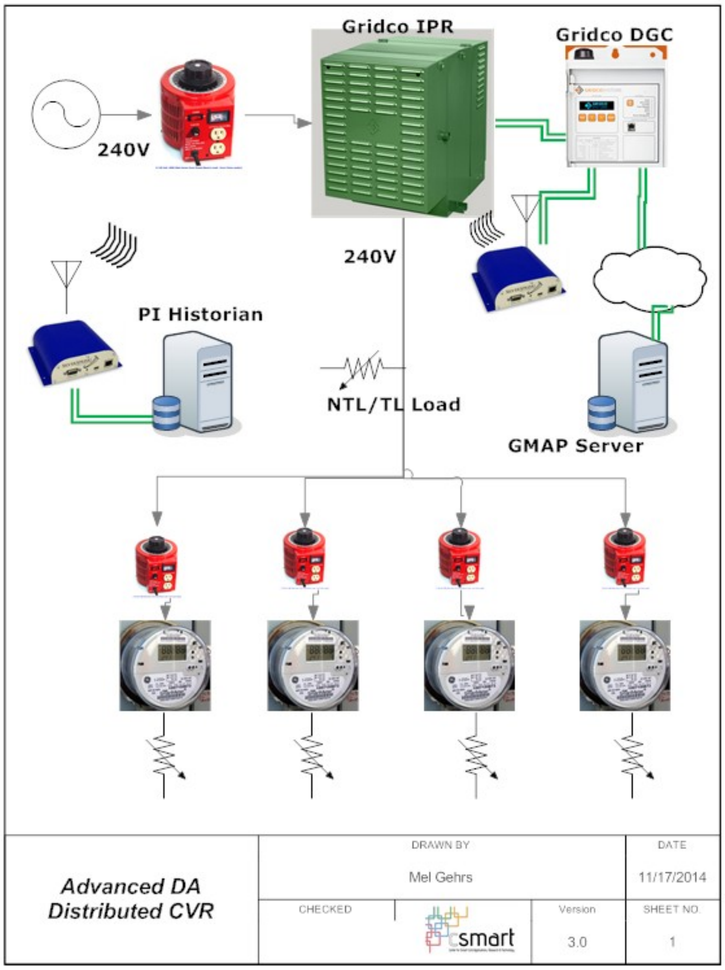
Secondary Objectives

- Demonstrate Distributed Power Factor control
- Demonstrate Distributed Harmonic Mitigation
- Demonstrate AMI + DA convergence
- Demonstrate peer to peer communication capability and limitations
- Demonstrate the use of LUA scripting to provide distributed intelligence and analytics in the SSN NIC.

WORK PLAN

Figure 2 provides a high level test lab configuration. The general setup requires the Gridco Systems IPR and DGC, as well as SNN Bridges and NICs in meters. It also requires the ability to simulate instability on the grid. The diagram shows use of Variac to vary the voltage on the line as well as a load to simulate NTL/TL load. The processes within the work plan will continue to shape the diagram. See Equipment section of this document for further details.

Figure 2:



The work plan is divided into four (4) phases outlined below:

1. **Discovery, Planning and Design**
   a. Determine the relevant stakeholders and identify their needs
   b. Determine the objectives of the project
   c. Determine requirements – develop a detailed list of requirement that will be used in the development of lab and test design and prove solutions

2. **Development**
    a. Determine the lab design based on the requirements. What equipment and what configurations will we need?
    b. Build the design-Procure and install the proposed lab equipment
    c. Validate Equipment installed are operational.
3. **Testing of CVR**
    a. Systems testing and user acceptance testing to ensure functionality and that user requirements are met in CVR.
    b. Run "on/off" protocol, or step through voltage range using IPR to measure CVR factor for subject test loads.
    c. Determine energy savings or peak reduction benefit of using local voltage control to augment medium voltage CVR approaches: i) local impact and ii) feeder level impact
4. **Testing of TL and NTL**
    a. Systems testing and user acceptance testing to ensure functionality and that user requirements are met in TL and NTL detection.
    b. Measure TL and NTL for range of IPR voltage settings
    c. Determine optimum setpoints/algorithms for minimizing losses
    d. Determine if an optimized approach can be defined to minimize overall energy consumption leveraging CVR and loss reduction.

Phase 1: Discovery, Planning and Design (4 weeks)

In this phase we want to lay the groundwork for building out the testing environment.

- Determine:
    - Project goals
    - Location
        - IIT location for equipment for various tests and use cases.
        - Special equipment from facilities
            - 240 input voltage and must support 1kW per load (heat).
    - Equipment
        - Description
        - Logistics
    - Safety
        - Safety during installation and maintenance
        - Safety during operation and demonstration
    - Terms and Conditions

Activities

Identify and meet with Stakeholders

- We will start by speaking with known stakeholders or their staff
    - ComEd Smart Grid team – Shay Bahramirad
    - ComEd AMI team – Craig Creamean
    - ComEd DA team – Carol Bartucci

    - IIT Sponsor – Dr. Shahidehpour
    - SSN Sponsor – Nipesh Patel
- Meet with Gridco Systems
    - Identify logistical, lab needs
    - Access web based DGC to develop preliminary communication protocols
    - Identify testing methodology for CVR and TL/NTL applications.
- Identify key resources needs from IIT, SSN and ComEd.

Determine Requirements

- Requirements will be determined by the testing/research objectives, and will then drive the design of the lab.
- Develop project plan and testing methodology.
- Identify detailed BOM (Bill of Materials) and equipment providers

<u>Deliverables</u>

1. Stakeholder interview notes (Word document)
2. Requirements document (Word/or Excel)
    a. Project goals with detailed key measurements, validation points
    b. Location
    c. Equipment – as stated in this document
    d. Safety
3. Terms and Conditions
4. Build-out plan
    a. Will include lab design and layouts
    b. Wiring diagram
5. Establish work, meeting schedules

Phase 2: Development (6 weeks)

<u>Activities</u>

Procure Equipment

- Procure lab space needed for testing
- Procure miscellaneous equipment
- Arrange for delivery of Gridco Systems IPR and DGC
- Assemble and perform acceptance

Installation

- Oversee electrical/physical installation
- SSN Rep present for Networking Installation
- Safety Training, if necessary

Configuration and Scripting

- Network configurations
- Gridco Systems controller configurations

- LUA scripting
- XML schema needed:
  - Meter data
  - Meter kw
  - Time
  - NTL exception rules

Validation

- Network Connectivity
- Test operation of all required equipment

Deliverables

1. Determine testing criteria, conduct operational tests for connectivity and validate installation.
2. Final Layout Documents, final materials list
3. Completed lab setup

Primary Objective Testing

Phase 3: Voltage Control and CVR Testing and Validation (8 weeks)

Activities

Establish and Test voltage control

- Develop test procedure to test voltage control
- Develop test procedure to test CVR implementation

Collect and Verify Data

- Perform voltage control test and verify data accuracy and results
- Perform CVR tests and verify data accuracy and results

Deliverables

1. Test procedure for voltage control and CVR
2. Test results from both tests

Phase 4: Real Time TL and NTL calculations (8 weeks)

Activities

Establish and Test voltage control

- Develop LUA algorithm to calculate Losses
- Identify acceptable losses for typical circuits
- Develop testing procedure

Collect and Verify Data

- Perform TL/NTL calculation testing and verify data accuracy and results

Deliverables

1. LUA script for TL/NTL
2. Test procedures
3. Test results

Secondary/Future Testing

Phase 5: Power Factor Control (TBD)

Activities

Establish and Test Power Factor Control

- Identify Power factor distortion source (in field/ on campus or in lab)
- Develop test procedure to test PF control.

Collect and Verify Data

- Perform PF control test and verify data accuracy and results

Deliverables

- Test procedure PF control
- Test results

Phase 6: Harmonic Distortion Mitigation (TBD)

Activities

Establish and Test Harmonic Distortion

- Develop test procedure to harmonic distortion mitigation

Collect and Verify Data

- Perform harmonic distortion control verify data accuracy and results

Perform tests and verify data accuracy and results

Deliverables

1. Test procedure for harmonic distortion
2. Test results from both tests

TIMELINE

The overall project duration is expected to take 26 weeks for phases 1 – 4. Phases 5 and 6 will be developed and a plan timeline build once the lab is functional.

ACTIVITY	START	DURATION (Weeks)	COMPLETE
Phase 1 - Discovery, Planning and Design	11/17/2014	4	12/15/2014
Phase 2 - Development	12/1/2014	6	1/12/2015
Phase 3 - Voltage and CVR Testing and Validation	1/12/2015	8	3/9/2015
Phase 4 - Real Time TL and NTL Calculations	3/9/2015	8	5/4/2015

RESOURCES

Project Team

Role	Person	Organization	Responsibilities
Project Manager	John Shen	SSN DA manager	Provides overall leadership of activities and deliverables. Responsibilities include: • Develops and maintains Project plan, scope and schedules with the objective • Manages and supervises Project personnel • Provides and facilitates status and progress reviews to Project sponsors and participants
Team Lead	Patrick Burgess	IIT Student	Primary contact and support of IIT lab. Duties include: • Interface to facility and IIT staff • Provide lab space and facilities support • Provide technical direction
Process SME	Dan Doughty	WMP Consultant	Guides analytical processes and leads production of assigned deliverables. Responsibilities include: • Develops work products and deliverables • Executes quality assurance measures pertaining to deliverables • Coordinates knowledge transfer and documentation
Technical SME	Aleksi Paaso	ComEd EE	ComEd technical advisor – MicroGrids and DA strategy
Technical SME	Kaveh Aflaki	ComEd EE	ComEd technical advisor – AMI/Smart Meters

Technical SME	Mel Gehrs	SSN Data Scientist	• Guide overall technology development • Guide overall LUA scripting development
LUA Script Manager	Charles Fisher	SSN LUA Script Development	Write and debug LUA scripts
GridCo Systems POC	Jeff Lo	GridCo Systems	Provide support for GridCo System products and development

Equipment

The CSmart lab will obtain the following equipment that will be used or accessed throughout the duration of the project

Grid Devices

- 1 – Gridco Systems IPR (50KVA)
    - Family of multi-function, utility-scale power electronics hardware systems that combine series-connected voltage control, shunt-connected current control, embedded sensing, and control logic to simultaneously provide voltage regulation, VAR compensation, harmonic compensation, power monitoring, and more
- 1 – Gridco Systems DGC
    - Intelligent computing platforms that provide coordination and control, data logging, local analytics, data networking, and communications via Secure DNP 3.0 and Secure Web Services.
- 1 – 240 V 10A Variac
- 4 – 240 V 3A Variac
- 3 – GE I210+C Smart Meters with SSN NIC
- 1 – GE KIV2C Smart Meter with SSN NIC
- 2 – SSN eBridges

Software

- Web-based DGC control portal
    - Advanced suite of software that provides remote monitoring and control, data collection, actionable data analytics, feeder optimization, and seamless integration with SCADA, DMS and VVO applications.

Galvin Center Resources

- PI Server – historical database with computation capability
- Lab facilities and appropriate electrical power