Metrics and Benefits Reporting Plan

The Perfect Power Prototype

for the Illinois Institute of Technology

Contract ID: DE-FC26-08NT02875

Project Type: Renewable and Distributed Systems Integration (RDSI)

Revision: V2 - Draft Submittal

Company Name: Illinois Institute of Technology

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1. Introduction

This document represents the Metrics and Benefits Reporting Plan for ***The Perfect Power Prototype for the Illinois Institute of Technology***.

The Illinois Institute of Technology (IIT), in collaboration with Exelon, the Galvin Electricity Initiative (GEI), and other key partners (the team) propose to develop, demonstrate, promote, and commercialize a system and supporting technologies that will achieve "Perfect Power" at the main campus of IIT. A "Perfect Power" system, as defined by GEI, is a system that cannot fail to meet the electric needs of the individual end-users. Different types of end-users will have different needs and a Perfect Power system will have the flexibility to supply the power required by each type without fail. This Perfect Power Prototype design is replicable to campuses, complexes, developments, investor owned, and municipal electric systems. The IIT project will demonstrate a new regulatory model for improving electricity service, one where the consumer and utility work together to lower cost, improve reliability, improve energy efficiency, and lower carbon emission. IIT is fortunate to be located in a restructured electricity market where the Independent System Operator provides real time pricing, day ahead hourly markets, demand response payments, capacity payments, and access to competitive wholesale electricity markets. These new markets provide IIT with the economic incentive to invest in demand reduction and energy efficiency. In addition, IIT owns the site distribution system thereby saving money on utility distribution charges. Essentially, IIT can control and invest the distribution charge savings into site distribution system improvements. In contrast, some cities in Illinois whose residents pay full distribution system charges have not had any improvements to the local distribution systems in 50 or more years.

The following sets forth the objectives, benefits, key asset deployment milestones, Build and Impact Metrics, associated data collection, aggregation and analysis methods, monetary investments, baseline data, and collaboration/interaction with the DOE necessary to accomplish IIT's Perfect Power project.

1.1 Introduction to IIT Distribution System

1.1.1 Area Substation Supply

As shown in Figure 1, IIT's electricity is supplied by three separate circuits fed from the Fisk Substation. Three circuits supply the South Substation and two circuits supply the North Substation. To the South Substation, all circuits run entirely underground from inside Fisk to transformers inside the substation. Circuits Y1931 (green) and Y1936 (blue), run directly from Fisk, and Y1975 (red) runs from Fisk by way of Pershing Substation. To the North Substation, Y1931 and Y1936 run underground until they reach the east side of Interstate 90/94 at 35th Street. There, Y1931 emerges and runs north above ground approximately 2,000 feet to a point adjacent to the North Substation, then runs under the Metra train tracks and emerges into an outdoor transformer at the North Substation. Y1936 continues underground to the same location and emerges to enter another outdoor transformer. Y1975 does not supply the North Substation. Each circuit is rated at 7MW using 7MW cable. IIT's highest peak load in the last two years was approximately 10MW. Since the system is designed to supply IIT with one of the three circuits out of service, the supply system has a maximum usage rating of 14MW.

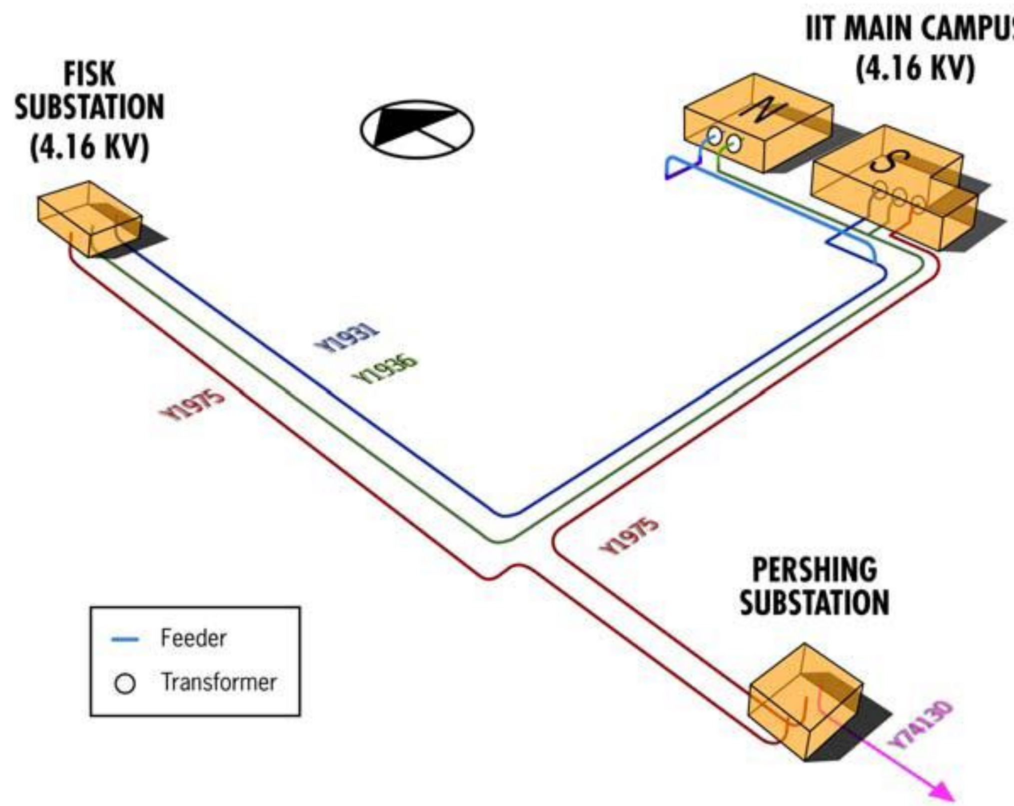


Figure 1: ComEd Supply to IIT

1.1.2 Campus Distribution System

IIT's existing 4,160V campus distribution system (Figure 2) consists of the ComEd supply circuits, supply breakers, a north and a south substation, feeder breakers, multiple building feeder cables, building transformers, and transformer supply breakers. Most of IIT's buildings have redundant feeds and the majority of these can achieve some level of substation redundancy. However, some of the buildings have no feeder redundancy and all of the switches on campus are manual. Some feeders are nearing their rated capacity. Some cable has been recently upgraded to 12KV. The Perfect Power project will transform the IIT campus distribution system into a high reliability distribution system (HRDS) as shown in Figure 2.

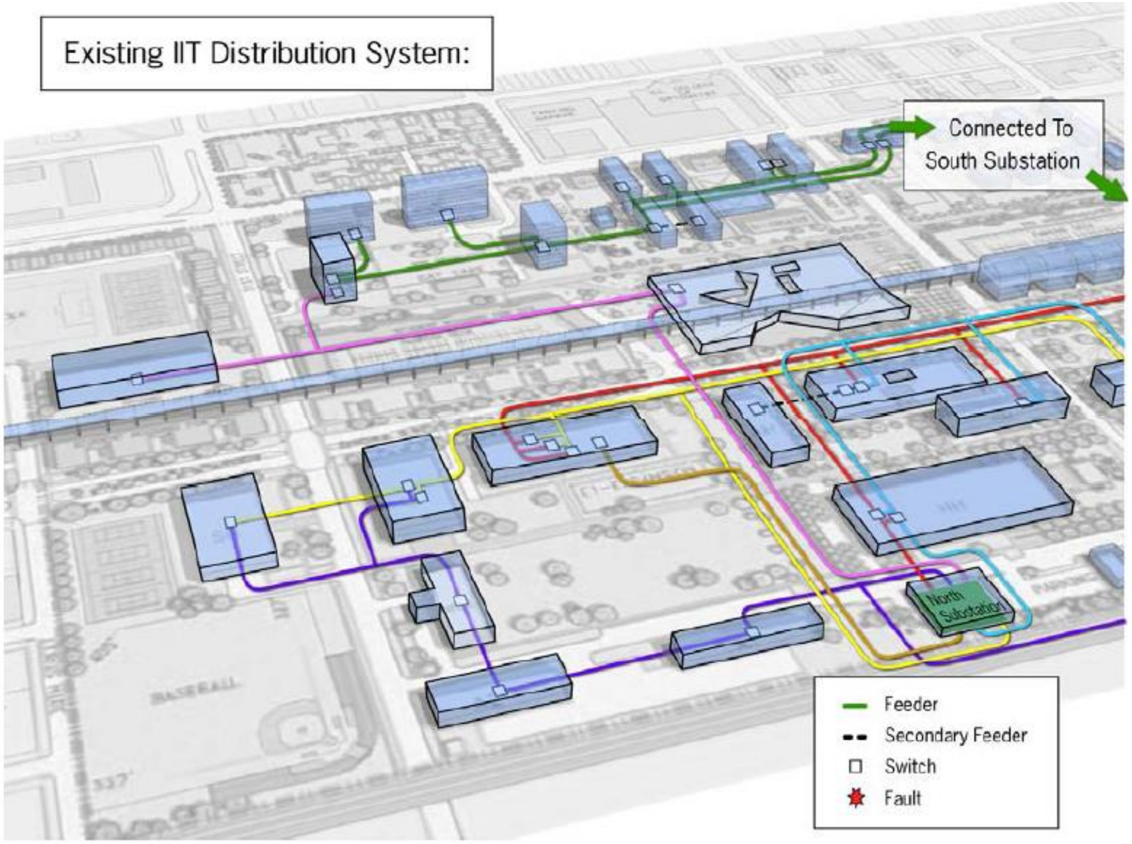


Figure 2: Existing Campus Distribution System

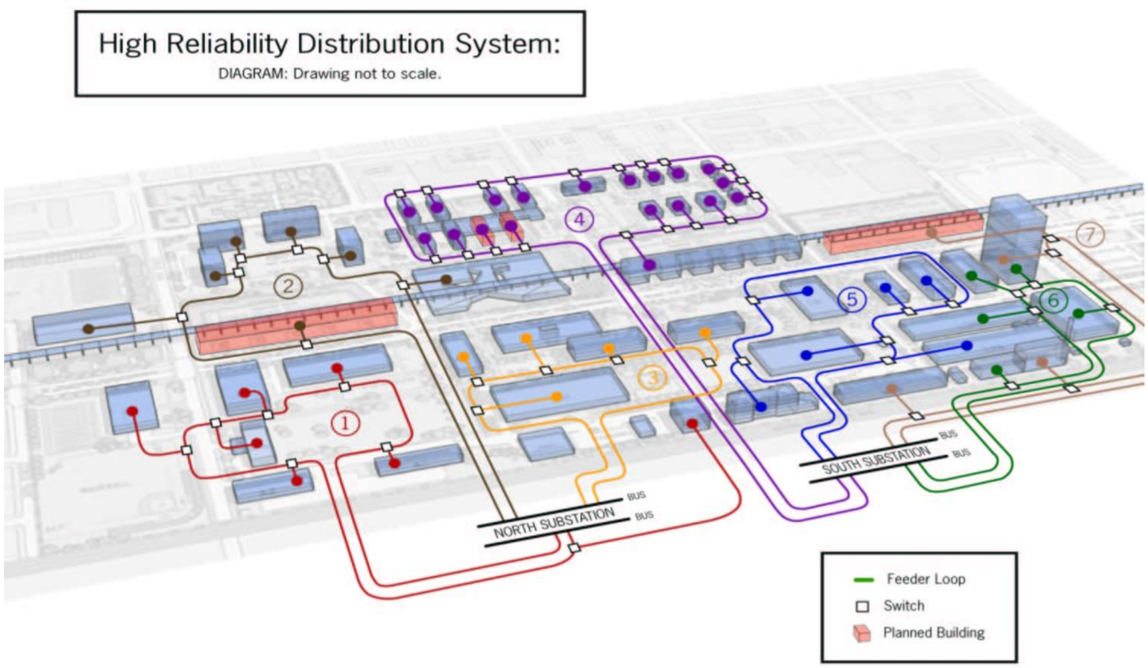


Figure 3: Proposed Campus Distribution System

1.2 Project Overview

The Perfect Power Prototype for the Illinois Institute of Technology is a Renewable and Distributed Systems Integration (RDSI) project.

The project team will demonstrate a replicable model for leveraging advanced technology to create microgrids which automatically respond to utility, Independent System Operator, and electricity distribution system signals, changes, and interruptions in a way that provides key demand reduction support and increased reliability. The proposed framework provides a systematic approach to build a foundation for perfect power. The team will engage in a five-phase research, development and demonstration project that will use continuous improvement methods to bring Perfect Power to the IIT campus and showcase Perfect Power principles to the industry. The phased approach provides utilities, land developers, municipalities, and campus settings across the country with a means to achieve Perfect Power in economically viable steps.

- **Phase I** – will prepare IIT's infrastructure for Perfect Power improvements. A conceptual design will be established and campus substation supply will undergo reliability improvements. IIT will conduct building energy efficiency upgrades and a detailed design will be completed for the campus distribution system.
- **Phase II** – will address key technology gaps identified in GEI research. These include advanced distribution fault detection, ZigBee wireless infrastructure, demand response control, advanced sensing and advanced distribution controls. Technologies developed in Phase II will be available for pilot testing.
- **Phase III** – will provide the capability for IIT to provide ancillary services including demand response and spinning reserve by modifying the two existing 4MW gas turbines and deployment of the first version of the Intelligent Distribution Controller. This new capability will provide for approximately 60% permanent peak daily peak load reduction capability.
- **Phase IV** – will be the deployment of the advanced campus distribution system based on S&C Electric's High Reliability Distribution System (HRDS) design. This design leverages seven feeder loops working in concert with intelligent high-speed switches to isolate any single fault without interruption of power to buildings. This phase also includes an upgrade to the IPPSC to communicate with the automated switches and provide for demand response of major campus loads.
- **Phase V** – will be the deployment of campus distribution level peak load reduction, uninterruptible power, solar photovoltaic, and the final version of the IPPSC as well as the demonstration of a microgrid energy storage and electric vehicle integration. This will provide for full demand response capability including interface with building control systems, building diesel and natural gas fired backup generators, and uninterruptible power sources. This will provide for full IIT Perfect Power Prototype capability.

The overall objectives of the project include:

1. The achievement of system-wide Perfect Power for IIT's electric power conditions and demonstration of its technological viability through the implementation of distributed energy (DE) and advanced sensing, switching, feeder configuration, and controls.
2. 50% peak demand reduction capability when called upon by Exelon/PJM Interconnection (PJM).

3. 20% permanent peak demand reduction from the 2007 annual peak demand.

4. Deferral of Commonwealth Edison (ComEd) planned substation upgrades due to the demand reduction achieved.

5. Demonstration of the economic value of Perfect Power, specifically the avoidance of outage costs, investment avoidance, and the introduction of significant savings and revenue from providing ancillary services in a restructured electricity market.

6. A design that can be replicated to any campus or community.

7. Promote the Perfect Power prototype.

1.3 Project Benefits

A power system that never fails to meet the customer's every functional need but is out of the financial reach of that customer is not perfect. Perfect Power meets the economic needs of the customer as well as the functional. The IIT Perfect Power prototype demonstrates that the very improvements that make it functional also make it affordable – not only saving the customer money but in some cases producing revenue. IIT's Energy Master Plan specifies a vision that provides an efficient and effective energy system that enables and facilitates the planned university expansion and supporting facilities, faculty, staff and research space. The Strategic Objectives are to provide the required reliability to the facilities, manage costs, provide for peak power cost mitigation, reduce the campus's carbon footprint, and provide for employee and student safety. In addition, the Perfect Power prototype is designed to expand research and education grant opportunities. Energy consumption at IIT is expected to increase with added students, staff, residents, research companies and tenants contributing to the growing use of campus facilities. In addition, by 2010, two new resident halls are planned to accommodate the increase in facility usage. The proposed Perfect Power prototype addresses a number of existing and future campus needs. The campus is outgrowing the existing electrical distribution system in several areas and critical components are beyond or fast approaching the end of their useful life. This Perfect Power Prototype provides an opportunity to replace worn out components while applying the Perfect Power design in such a way as to eliminate extended outages at the campus.

1.3.1 Avoided Distribution System Upgrades

ComEd has indicated that the Perfect Power prototype will defer pending upgrades to the Fisk substation totaling approximately $2,000,000. In addition, planned new housing on east campus combined with expanded academic and research facilities throughout campus will exceed the capacity of the current site electricity distribution system. IIT was pursuing a third substation on east campus at a cost of over $5,000,000. The Perfect Power design will meet the new electricity demand and address reliability concerns without installing a new substation.

1.3.2 Reduced Energy Costs

The Perfect Power system positions IIT to purchase lower cost real time electricity and reduce peak energy demand which costs more. An analysis which compared the current electricity procurement agreement against the 2005 and 2006 real-time prices, determined that IIT would have saved approximately $1,000,000 per year purchasing electricity in real time while using the generation to cap the electricity price. IIT and ComEd are located in the Pennsylvania, New Jersey, and Maryland (PJM) Independent System Operator (ISO), which provides for the opportunity to purchase lower cost electricity in real time. Entering the real-time markets without a means for hedging hourly price spikes could result in a sizable increase in electrical costs. Electricity prices can reach $1 or more per KWh in peak periods. However, the IIT proposed on-site generation can be operated to mitigate peak demand prices, effectively capping prices at the operating costs of the on-site generation - 8 to 10 cents/KWh.

1.3.3 Reliability and Power Quality Benefits

The IIT campus experiences on average three outages per year resulting in restoration costs, lost experiments that in some cases cannot be recovered and lost productivity. The Perfect Power prototype will ensure that no single failure in any of the distribution system feeder circuits will result in an interruption of power. In addition, the on-site generation will be expanded to carry the entire campus's electricity demand during ComEd supply interruptions. This will provide for the automatic restoration of electricity to all campus facilities within 5 minutes of a ComEd supply outage. Critical campus loads/equipment has or will be equipped with Uninterruptible Power Sources (UPS) to bridge the 5 minute gap. The measurable costs of power outages are about $500,000 per year. With Perfect power, the IIT campus would also experience a number of benefits that are not currently measured. This includes extended equipment life due to improved power quality.

1.3.4 Improved Safety

The Perfect Power system will provide IIT with a significantly more robust energy system that can respond to weather, aging, and other threats, ensuring power to students, teachers, and tenants, during emergencies. In addition the Perfect Power system will automate high voltage switching throughout the campus, eliminating the potential for personal and equipment damage resulting from human error.

1.3.5 Ancillary Services

The Perfect Power system will position IIT to provide ancillary services to ComEd and PJM. This includes 10MW of spinning reserve, 3MW of permanent demand reduction, and the ability to supply imaginary power or VAR's. This provides a unique opportunity to participate in real time pricing, spinning reserve, capacity, and energy demand markets. The IIT Perfect Power system can leverage two 4MW turbines to provide ancillary services to the PJM ISO.

1.3.6 Economic Development

The proposed improvements to the IIT electrical distribution system and the Perfect Power prototype position IIT as a test bed for research and education opportunities. IIT can serve as a living laboratory for the most advanced distribution system concepts and control technologies. This includes ComEd IPRO projects, Federal and State research grants, and NSF research and education grants. Implementation of perfect power at IIT will provide a powerful resource for attracting students and government/industry funding. The Electrical Engineering school expects to raise an additional $1,000,000 per year due to the added campus features and functions.

The smart grid functions supported by the IIT Perfect Power project are presented on Table 1.

Specific smart grid benefits, supported by the IIT Perfect Power project and aligned with the DOE benefits framework, are presented on Table 2.

Table 1: Smart Grid Functions Supported by Project

Smart Grid Functions	
Fault Current Limiting	NO
Wide Area Monitoring, Visualization, & Control	NO
Dynamic Capability Rating	NO
Power Flow Control	NO
Adaptive Protection	YES
Automated Feeder Switching	YES
Automated Islanding and Reconnection	YES
Automated Voltage & VAR Control	NO
Diagnosis & Notification of Equipment Condition	NO
Enhanced Fault Protection	YES
Real-time Load Measurement & Management	YES (at campus level)
Real-time Load Transfer	NO
Customer Electricity Use Optimization	YES

Table 2: Smart Grid Benefits Supported by Project

Benefit Category	Benefit Sub-category	Benefit	Provided by Project
Economic	Market Revenue	Arbitrage Revenue (consumer) Capacity Revenue (consumer) Ancillary Service Revenue (consumer)	NO
	Improved Asset Utilization	**Optimized Generator Operation (utility/ratepayer)** Deferred Generation Capacity Investments (utility/ratepayer) **Reduced Ancillary Service Cost (utility/ratepayer)** Reduced Congestion Cost (utility/ratepayer)	**YES**
	T&D Capital Savings	Deferred Transmission Capacity Investments (utility/ratepayer) **Deferred Distribution Capacity Investments (utility/ratepayer)** **Reduced Equipment Failures (utility/ratepayer)**	**YES**
	T&D O&M Savings	Reduced Distribution Equipment Maintenance Cost (utility/ratepayer) **Reduced Distribution Operations Cost (utility/ratepayer)** Reduced Meter Reading Cost (utility/ratepayer)	**YES**
	Theft Reduction	Reduced Electricity Theft (utility/ratepayer)	NO
	Energy Efficiency	Reduced Electricity Losses (utility/ratepayer)	NO
	Electricity Cost Savings	**Reduced Electricity Cost (consumer)**	**YES**
Reliability	Power Interruptions	**Reduced Sustained Outages (consumer)** **Reduced Major Outages (consumer)** **Reduced Restoration Cost (utility/ratepayer)**	**YES**
	Power Quality	**Reduced Momentary Outages (consumer)** **Reduced Sags and Swells (consumer)**	**YES**
Environmental	Air Emissions	**Reduced Carbon Dioxide Emissions (society)** **Reduced SO_x, NO_x, and PM-2.5 Emissions (society)**	**YES**
Security	Energy Security	Reduced Oil Usage (society) Reduced Wide-scale Blackouts (society)	NO

2. Key Technology Development and Asset Deployment Schedule

IIT's key asset deployment schedule, as identified in the Project Management Plan, is included as Appendix A – Project Timeline. Key baseline data will be gathered and analyzed prior to asset deployment and post-deployment data will be gathered and analyzed in accordance with this Metrics and Benefits Plan and DOE reporting frequencies. See Section 4 of this report for more information regarding Baseline Data, including proposed timelines, data sources, and analysis methods. In addition to the attached integrated schedule, key project milestones are included as a list in Table 3 below.

Table 3: Project Milestones

Phase/Task	Milestone	Planned Completion Date
Phase I – Perfect Power Foundation	Milestone P1: Completion of Perfect Power Design	April 30, 2010
Phase II – Multi-year Research Phase		
Task 1.0 – Advanced Distribution Automation and Recovery System	Milestone P211: Completion of dNetSim Communication Model	September 30, 2009
	Milestone P212: Completion of dNetSim Visualization Platform	September 29, 2010
	Milestone P213: Autonomous Agent Infrastructure for Real Time Control	September 29, 2011
	Milestone P214: Autonomous Agent Infrastructure for Centralized and Distributed Control	September 27, 2012
	Milestone P215: Pilot Demonstration of Autonomous Agent Infrastructure	September 27, 2013
Task 2.0 – Buried Cable Fault Detection and Mitigation	Milestone P221: Completion of the Simulation on IIT's Distribution Network	April 1, 2010

Phase/Task	Milestone	Planned Completion Date
	Milestone P222: Identification of the Best FDM for IIT's Distribution Network	September 29, 2011
	Milestone P223: Pilot Demonstration of FDM in IIT's Distribution Network	September 27, 2013
Task 3.0 – Intelligent Perfect Power System Controller	Milestone 231a: Completion of IPPSC Version 1 Software Specification	July 15, 2009
	Milestone 231b: Completion of IPPSC Version 1 Software	December 31, 2009
	Milestone 231c: Completion of IPPSC Version 1 Bench Testing	April 30, 2010
	Milestone 232a: Completion of IPPSC Version 2 Software Specification	March 5, 2010
	Milestone 232b: Completion of IPPSC Version 2 Software	July 21, 2010
	Milestone 232c: Completion of IPPSC Version 2 Bench Testing	November 24, 2010
	Milestone 233a: Completion of IPPSC Version 3 Software Specification	March 4, 2011
	Milestone 233b: Completion of IPPSC Version 3 Software	July 11, 2011
	Milestone 233c: Completion of IPPSC Version 3 Bench Testing	November 15, 2011
Task 4.0 – Advanced ZigBee Wireless	Milestone P241: Completion of the Design and Development of Interference Avoidance Techniques	September 30, 2009

Phase/Task	Milestone	Planned Completion Date
	Milestone P242: Completion of the Design and Development of Self-forming and Self-healing Cluster-tree ZigBee systems	September 29, 2010
	Milestone P243: Completion of the Design and Development of MAC Layer Protocol to Achieve Energy-efficient Access for Cluster-tree Networks	September 29, 2011
	Milestone P244: Completion of ZigBee Installation Plan and Energy Efficient Routing Algorithm	September 27, 2012
	Milestone P245: Pilot Demonstration of ZigBee Wireless Technology for Implementing Energy Efficiency Programs	September 27, 2013
Phase III – Ancillary Service Demonstration	Milestone P31: IPPSC V1 Installed	February 18, 2011
	Milestone P32: Engine Start to Full Load within 10 Minutes	August 2, 2009
Phase IV – Distribution System Automation Demonstration	Milestone P41: HRDS Installed	January 19, 2013
	Milestone P42: Substation Automation Compatible to HRDS	January 19, 2011
	Milestone P43: IPPSC V2 Installed	August 3, 2011
Phase V – Distribution Level Peak Load Reduction Demonstration	Milestone P51: Load Reduction Controller Installed	April 5, 2012
	Milestone P52: IPPSC V3 Installed	December 27, 2012
	Milestone P53: Solar PV Installed	December 20, 2011
	Milestone P54: UPS Installed at Critical Buildings	December 21, 2011
	Milestone P55: A Battery Storage System Commissioned	December 21, 2011

Phase/Task	Milestone	Planned Completion Date
	Milestone P56: Electric Vehicle Charging Stations Commissioned	December 21, 2011
Overall Project	Milestone PRO: 50% Peak Load Reduction Capability	September 27, 2013

3. Storage System Performance

The storage system for this project is for a **Grid-Interactive ZESS POWR™** Platform Configuration utilizing ZBB's standard ZESS 50V3 modular regenerative flow battery type of energy storage. The complete system includes the ZESS energy storage modular enclosure and the Proprietary Hybrid Power Conversion System (PCS) – ZESS POWR PECC - for a completely regulated energy storage system ready for interconnection to a range of modular, flexible, energy sources and outputs, while performing power and energy management needs. All this is done to a 208VAC, 3-phase (or optionally 480/4160/15kVAC), grid connection, as required. There is minimal site preparation, minimal installation, and minimal commissioning to afford "plug and play" connections. The control interface to the ZESS POWR is via Modbus.

The applicability of energy storage applications is listed in the Table 4. These applications will be demonstrated either individually or simultaneously. For example, the energy storage will enable the IIT system to shift energy consumption (from the grid) from peak hours to off-peak hours. This includes both "Electric Energy Time Shift" and "Time-of-Use Energy Cost Management". During summer when load is high, the energy storage will provide "Electric Supply Capacity" by actually serving load. During spring or fall when load is low, the energy storage will provide "Electric Supply Reserve Capacity" by standing by and only serving load during emergency conditions or when called upon by PJM. The energy storage will obviously improve "Electric Service Reliability" and "Electric Service Reliability". All these applications will be automated when IPPSC fully functions. Currently, IIT system participates in the PJM ancillary services market by self-generating (using gas turbine generators) or shedding load when called upon by PJM. Thus, the mechanism is already in place and the addition of energy storage will give IIT more flexibility in participating in the ancillary services market.

Table 4: Applicability of Energy Storage Applications

Energy Storage Applications	**Applicability to This Project**
Electric Energy Time Shift	Yes
Electric Supply Capacity	Yes
Load Following	No
Area Regulation	No
Electric Supply Reserve Capacity	Yes
Voltage Support	No
Transmission Support	No
Transmission Congestion Relief	No
T&D Upgrade Deferral	No
Substation Onsite Power	No
Time-of-Use Energy Cost Management	Yes
Demand Charge Management	No
Electric Service Reliability	Yes
Electric Service Power Quality	Yes
Renewables Energy Time Shift	No
Renewables Capacity Firming	No
Wind Generation Grid Integration, Short Duration	No
Wind Generation Grid Integration, Long Duration	No

3.1 System Characteristics

The system characteristics of the battery storage system in this project are listed in Table 5.

Table 5: Storage System Characteristics

Items	**Storage System Characteristics**
Location	Loop 1
Weight, footprint, and dimensions	Modular DC bus NEMA 3R enclosures (ZESS 50V3 - 72"W x 25"D x 96"H) Modular Enclosure: 10'W x 40'L x 11.5'H
Transportability	Transportable via crane and truck, but currently planned to have a fixed location.
MW nameplate rating (including depth of discharge, operating conditions)	Power (with DC to AC inverter): 250kW - Nominal Power Point-of-Connection (POC): 208VAC, 3-phase, 1 x 125kW system output - Nominal ZESS Charge rate max: 17.0kW per unit - Nominal ZESS Discharge rate max: 25.0kW per unit - System Charge rate range: 0 to 170.0kW (From PV and / or Grid input) - System Discharge rate range: 0 to 250.0kW (From PV and / or ES output)
MWh nameplate capacity (including depth of discharge, operating conditions)	Energy: 500kWh - Available Energy @ 100% SOC: 50kWh (1 x ZESS 50V3) - Base System Energy @ 100% SOC: 10x 50kWH = 500kWH (expandable)
Energy density	75 to 85 watt-hours per kilogram
Specific energy and power	75 to 85 watt-hours per kilogram

System components (e.g., storage module, power conversion system, cooling system, balance of plant)	Power Input Command Control:
	- Requires customer power command signal (-10 to 10V analog signaling)
	- Communication bus Interface for use with customer system control; such as:
	  - Start / Stop commands
	  - Charge / Discharge level
	  - System status (from ZBB to customer)
	-30*C to 50*C Standard operating range (hot and/or cold packages available upon request)

3.2 Data Measurements

The data measurements of the battery storage system in this project are listed in Table 6.

Table 6: Data Measurements of the Battery Storage System

Items	**Data Measurements**
Operational mode	To be recorded
Import energy signal	To be recorded
Export energy signal	To be recorded
kW input	To be recorded
kW output	To be recorded
Voltage	To be recorded
VAR	To be recorded
Amp	To be recorded
kWh	To be recorded
Frequency	To be recorded
Power factor	To be recorded
Battery system state of charge	To be recorded
Response time	To be recorded
Number of cycles	To be recorded
Harmonics	To be recorded
Hourly electricity price	To be recorded

3.3 System Performance Parameters

The system performance parameters of the battery storage system in this project are listed in Table 7.

Table 7: System Performance Parameters

Items	**System Performance Parameters**
Technical	
Scheduled maintenance down time	4 hours/week
Down time associated with State of Charge (SOC)	To be reported at the end of the operations
Unscheduled down time	To be reported at the end of the operations
Plant availability**	To be reported at the end of the operations
Number and duration of failure incidents	To be reported at the end of the operations
Energy dispatched on day-to-day and lifetime basis	To be reported at the end of the operations
Round-trip efficiency (RTE)	70%
Ability to follow Automatic Generation Control (AGC) signal (regulation only)	Yes
Ramp rate (charge/discharge)	170/250
Capacity degradation	No loss of performance from repeated cycling that typically causes electrode material deterioration
Economic	
Engineering and design costs	
Capital cost (i.e., equipment capital and installation) ($)*	$1,014,100
Capital cost ($/kWh & $/kW)*	$2.03/kWh, $4,056/kW
End of life disposal cost ($)**	To be reported at the end of the operations
End of life value of plant and equipment**	To be reported at the end of the operations
Operating cost (activity based, non-fuel, by application plus monitoring)	Ignorable
Maintenance cost (by cost category)	Cost of cell stacks and replacing cell stacks
Environmental Health & Safety (EHS)	
Operating temperature	30*C to 50*C
Flammability	No
Material toxicity	Commonly available chemicals, zinc and bromide
Recyclability	Cell stacks replacable
Other	TBD

*: To be reported at the start of the operations
**: To be reported at the end of the operations

3.4 Projected Performance Parameters

The projected performance parameters of the battery storage system in this project are listed in Table 8.

Table 8: Projected Performance Parameters

Items	Projected Performance Parameters
Cycle life (define basis for estimation, e.g. based on 80% capacity degradation, or other metrics)	1000's of deep discharge cycles over the service lifetime
Calendar life (define basis for estimation)	20+ years of service design life
Total life cycle maintenance cost	Cost of cell stacks and replacing cell stacks
Total life cycle operating cost	Ignorable
Capacity degradation	No loss of performance from repeated cycling that typically causes electrode material deterioration
Capital cost ($/kWh over lifetime)	$2/kWh

4. Build and Impact Metrics

This section contains each of the Build and Impact Metrics that IIT will report. The metrics apply to the total project supported by the DOE and IIT cost-shared funds. Included in the tables (referenced as Appendices in the following sub-sections) are explanations of the data collection methods, frequency, and aggregation and analytical methods that will be used to determine the metrics and the associated benefits achieved by the IIT Perfect Power project.

Build metrics reports, including relevant monetary investments and pricing, will be submitted by the end of month following each calendar quarter starting in January 2011 until all project assets have been deployed.

4.1 Monetary Investments

IIT will report funds that have been expended for the deployment of the Perfect Power project. The report will include the DOE grants and the cost share of all recipients. Monetary Investments metrics that will be reported by IIT are highlighted in green in Table 9 on the next page:

Table 9: Applicable Monetary Investment Build Metrics

AMI				Customer Systems					
Monetary Investment	AMI Back Office Systems	Communication Equipment	AMI Smart Meters	Customer Back Office Systems	Customer Web Portals	In Home Display	Smart Appliances	Programmable Controllable Thermostats	Participating Load Control Device
DOE	-	-	-	-	-	-	-	-	-
Cost Share	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-	-
Other Assets and Costs that do not align with the categories listed above:									
Electric Distribution									
Monetary Investment	Back Office Systems	Distribution Management System	Communications Equipment / SCADA	Feeder Monitor / Indicator	Substation Monitor	Automated Feeder Switches	Capacitor Automation Equipment	Regulator Automation Equipment	Fault Current Limiter
DOE	-	-	-	-	-	-	-	-	-
Cost Share	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-	-
Other Assets and Costs that do not align with the categories listed above:									
Electric Distribution – Distributed Energy Resources (DER)									
Monetary Investment	DER Interface / Control Systems	Communication Equipment	DER / DG Interconnection Equipment	Distributed Generation (DG)	Renewable DER	Stationary Electricity Storage	Plug-in-Electric Vehicles		
DOE	-	-	-	-	-	-	-		
Cost Share	-	-	-	-	-	-	-		
Total	-	-	-	-	-	-	-		
Other Assets and Costs that do not align with the categories listed above:									
Electric Transmission									
Monetary Investment	Back Office Systems	Advanced Applications (Software)	Dynamic Rating Systems	Communication Equipment	PDC	PMU	Line Monitoring Equipment		
DOE	-	-	-	-	-	-	-		
Cost Share	-	-	-	-	-	-	-		
Total	-	-	-	-	-	-	-		
Other Assets and Costs that do not align with the categories listed above:									

4.2 Equipment Asset Build Metrics

IIT will identify the equipment asset build metrics throughout the plan and reporting process. IIT will report project metrics for the assets and programs funded by the DOE and cost share.

4.2.1 Electric Distribution Assets

IIT will deploy distribution automation in the loops that are connected to the North Substation. These loops comprise about 50% of IIT's total distribution system. We intend to enable automatic feeder switching as part of this distribution automation implementation. We expect to be able to improve reliability. Asset Summary:

- Project: Loop 1 (5 switches), Loop 2 (7 switches), Loop 3 (3 switches)

Appendix B1 presents the Build Metrics for IIT's Electric Distribution Assets and their associated data collection methods, frequency, and aggregation and analytical methods.

4.2.2 Distributed Energy Resources

Photovoltaic (PV) system will be deployed as part of this project. Asset Summary:

- Project: One PV system on the roof of Siegel Hall
- Project: ZESS 50V3 / 500kWH with 250kW ZESS POWR PECC (250 kW battery storage system on Loop 1 of of IIT's Perfect Power Prototype)
- Project: seven electric vehicle charging stations on the Perfect Power Prototype, connected to loops 2 and 3. Three Level 2 electric vehicle charging stations and one Level 3 charging station will be installed on Loop 2. Three Level 2 electric vehicle charging stations will be installed on Loop 3.

Appendix B2 presents the Build Metrics for IIT's Distributed Energy Resources and their associated data collection methods, frequency, and aggregation and analytical methods.

4.3 Pricing Programs

IIT is currently under a flat rate pricing program. Program Summary:

- Project: Flat Rate

Appendix B3 presents the Build Metrics for IIT's Pricing Program and their associated data collection methods, frequency, and aggregation and analytical methods.

IIT does not plan to participate in net metering program since IIT does not envision to have excess generation capacity available at any time in the new future. However, certain IIT buildings, with excess solar PV capacity (not all funded by this project), could participate in internal net metering by supplying partial loads at other IIT buildings. IIT does not participate in rate decoupling pricing program.

4.4 Impact Metrics

IIT will prepare and submit impact metrics reports which shall document and summarize the status of identification and quantification of impact metrics and cost-benefit data and analyses with respect to the pre-demonstration and projected baseline system configurations and the demonstrated system configuration. The first set of impact metrics data will be reported in MS Excel by October 31, 2012 covering data collected through September 30, 2012. Additional impact metrics data will be reported in concert with the development of the final report in late 2013. The impact metrics data submittals will distinguish between winter (October-March) and summer (April-September) data.

4.4.1 Project and System Metrics

IIT will identify the impact metrics as either project or system metrics throughout the plan and reporting process. IIT will report project metrics for impacts observed specific to the area project assets, functionality or programs are implemented. IIT will report system metrics for impacts observed on the entire campus distribution system.

4.4.2 AMI and Customer Systems

IIT owns its distribution system. With limited metering infrastructure, IIT can report monthly electricity usage, peak load on substation level, annual generation cost, annual electricity production, annual ancillary services cost on a totalized annual basis, meter operation cost on a totalized annual basis, CO2 on the substation level. In summary, the Impact metrics will include:

- Peak generation resources needed to meet peak demand compared to baseline which includes peak demand growth projections based on growth. (project)
- Electricity usage profile based on monthly data compared to base line estimates which include assumptions regarding usage, load growth and energy prices. (project)

Appendix C1 presents the Impact Metrics for IIT's AMI Assets and Customer Systems and their associated data collection methods, frequency and aggregation and analytical method.

4.4.3 Electric Distribution Systems

We expect to be able to improve reliability of our distribution system as a result of the distribution automation to be implemented. Automatic feeder switching will not prevent outages, but it will reduce the scope and duration of outage impacts. This will be accomplished through the automatic isolation and reconfiguration of faulted segments of distribution feeders via sensors, controls, switches, and communication systems. Also, automatic feeder switching can reduce or eliminate the need for a human operator or field crew for operating distribution switches. This saves time and reduces labor cost. In summary, the Impact metrics will include:

- Reliability indices including SAIFI, SAIDI/CAIDI, Outage Response Time. Operations personnel and reliability analysts will utilize data normalization techniques when necessary to ensure a consistent data set for the comparison (project).

- The number of major events like named storms will be measured and analyzed separately (project).
- Meter Operations costs will be based on the number of manual tasks that are automated compared with baseline projections (project).

Appendix C2 presents the Impact Metrics for IIT's Electric Distribution Systems and their associated data collection methods, frequency, and aggregation and analytical methods.

5. Baseline Data

This section provides the methods for how baseline information and forecasts will be developed for each Build and Impact Metric, including sources of data, how each metric will be estimated at project commencement, and appropriate calculations or analysis. IIT interprets the baseline as the forecasted impacts and benefits if the DOE funding had not been awarded. Indices in Year 2007 will be used as baseline. IIT, with the addition of Federal funding, will install and integrate an industry leading distribution automation devices that will spur greater demand reduction, energy savings, efficiency, and reliability. The year of 2007 was selected since it was the first full year when this project was funded in 2008. It was also the year when a project team was commissioned by the Galvin Electricity Initiative to study the feasibility of implementing perfect power concept in the IIT system.

In order to characterize the baseline data and projections for IIT's Build Metrics , IIT will conduct a thorough review of its budget capturing planned Build Metrics values had the Federal funding not been awarded. Additionally, in order to characterize the baseline data for IIT's Impact Metrics, IIT will compile all necessary sources of historical data for each Impact Metric in order to estimate project impact values had the Federal funding not been awarded.

Please refer to Appendix D – IIT's Baseline Build Metrics for Electric Distribution Assets.

6. Market Place Innovation Reporting

IIT's Perfect Power project will facilitate new jobs, products, services, and markets that will develop in response to the growth of the IIT microgrid. IIT's system will provide the foundation to collect substantial information, in regards to market place innovation, once the key electric distribution systems are in place. IIT will work in coordination with the DOE to provide and report on new programs and joint ventures with suppliers, as well as novel methods of taking advantage of the full functionality IIT's system provides.

7. Collaboration and Interaction

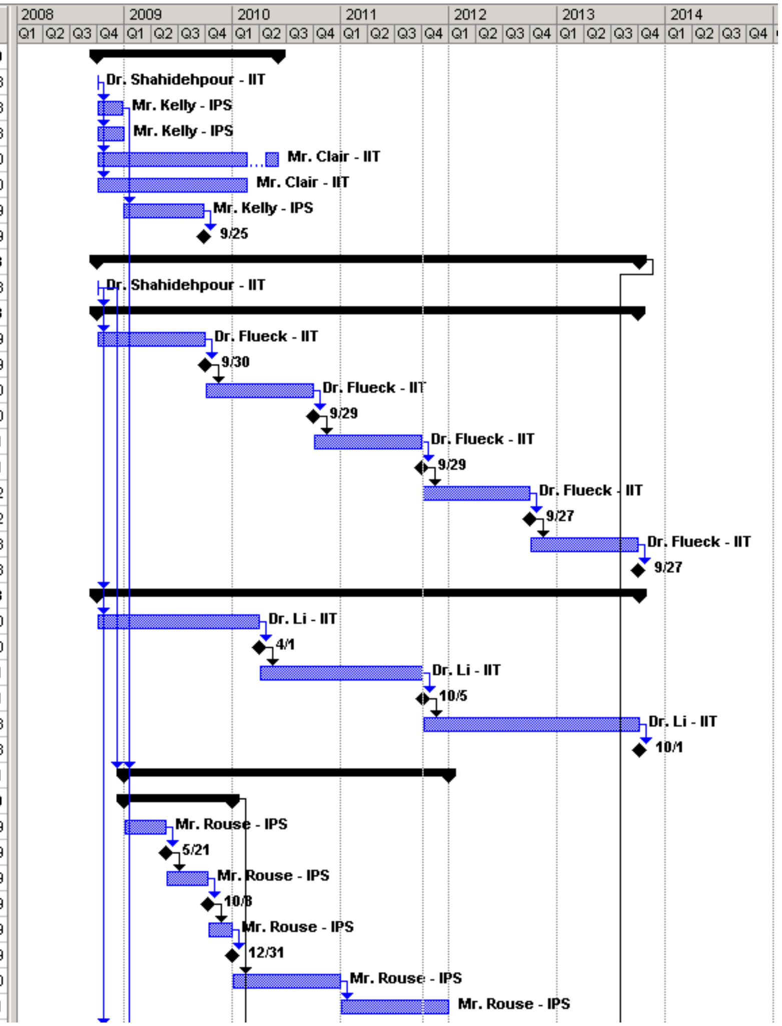
IIT will coordinate with local utility (ComEd) and system operator (PJM) so they can support data gathering and analysis related to generation resources and costs. Also, where appropriate IIT will coordinate and collaborate extensively with the DOE to ensure on time and on budget activities for IIT's Perfect Power project. Dr. Mohammad Shahidehpour, the PI of this project, will be the main contact for all collaboration and interaction between the DOE and IIT. Specific areas where collaboration is necessary include: 1) key deliverables (i.e. Project Management Plan, Metrics and Benefits Reporting

Plan, etc.), including plan reviews and timely submittals and 2) all on-going DOE and Federal reporting requirements (i.e. Quarterly Progress Reports, Quarterly Jobs reporting, Quarterly Federal Financial reporting, invoicing, etc.). In addition to working with DOE staff, IIT intends to collaborate and coordinate with the DOE to support other data requests or analysis that will improve the overall impact of the RDSI projects.

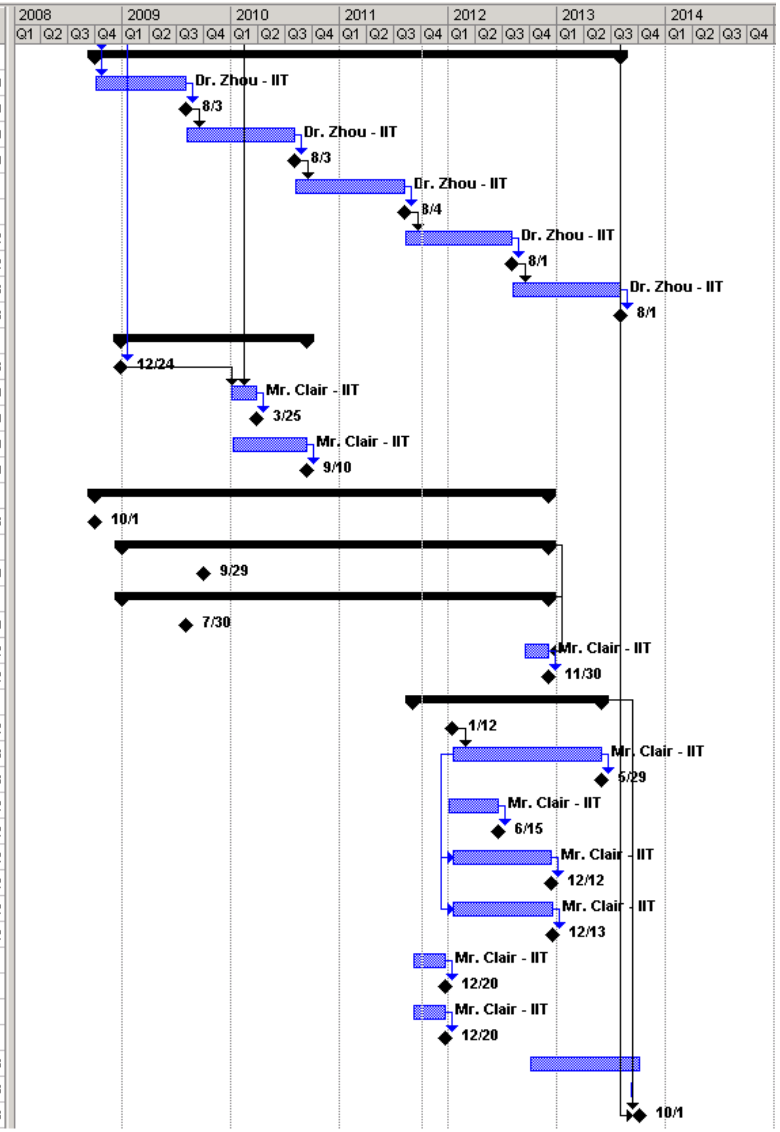
Appendix A – Project Timeline

The project timeline is shown below. Demonstration data collection related to the performance and impact of the deployed assets will start on October 1, 2012, when the IPPSC is expected to be fully functioning. A draft of the final report will be submitted by September 1, 2013, once month before the end of this project.

Task Name	Start	Finish
Phase 1 Perfect Power Foundation	**10/1/08**	**6/1/10**
Task 0.0 Revise Project Management Plan	10/1/08	10/1/08
Task 1.0 Conceptual Model	10/2/08	12/24/08
Task 2.0 ComEd/PJM Portal	10/2/08	12/30/08
Task 3.0 Energy Efficiency Upgrades	10/2/08	6/1/10
Task 4.0 ComED Substaion PM	10/2/08	2/17/10
Task 5.0 Perfect Power Design	12/25/08	9/25/09
Milestone P1: Completion of Perfect Power Design	9/25/09	9/25/09
Phase 2 Multi-Year Research Phase	**10/1/08**	**10/1/13**
Task 0.0 Revise Project Management Plan	10/1/08	10/1/08
Task 1.0 Distribution Automation	**10/2/08**	**9/27/13**
Subtask 1.1 dNetSim Communication Model	10/2/08	9/30/09
Milestone P211: dNetSim Communication Model	9/30/09	9/30/09
Subtask 1.2 dNetSim Visualization Platform	10/1/09	9/29/10
Milestone P212: dNetSim Visualization Platform	9/29/10	9/29/10
Subtask 1.3 Autonomous Agent Infrastructure	9/30/10	9/29/11
Milestone P213: Real-time Control	9/29/11	9/29/11
Subtask 1.4 Agent Infrastructure Extension	9/30/11	9/27/12
Milestone P214: Centralized and Distributed Control	9/27/12	9/27/12
Subtask 1.5 Agent Infrastructure Demo	9/28/12	9/27/13
Milestone P215: Pilot Demo	9/27/13	9/27/13
Task 2.0 Fault Detection and Mitigation	**10/2/08**	**10/1/13**
Subtask 2.1 Distribution Network Simulation	10/2/08	4/1/10
Milestone P221: Simulating IIT's Distribution Network	4/1/10	4/1/10
Subtask 2.2 FDM Identification	4/2/10	10/5/11
Milestone P222: Best FDM for IIT's Distribution Network	10/5/11	10/5/11
Subtask 2.3 FDM Pilot Demo	10/6/11	10/1/13
Milestone P223: Pilot Demo	10/1/13	10/1/13
Task 3.0 IPPSC	**1/2/09**	**12/29/11**
Task 3.1 IPPSC V1 Development	**1/2/09**	**12/31/09**
Task 3.1a IPPSC V1 specification	1/2/09	5/21/09
Milestone P231: Completion of IPPSC Specification	5/21/09	5/21/09
Task 3.1b V1 Software development	5/22/09	10/8/09
Milestone P232: IPPSC Software Development	10/8/09	10/8/09
Task 3.1c V1 Software QA and bench test	10/9/09	12/31/09
Milestone P233: IPPSC Software Testing	12/31/09	12/31/09
Task 3.2 IPPSC V2 Development	1/1/10	12/30/10
Task 3.3 IPPSC V3 Development	12/31/10	12/29/11



Task Name	Start	Finish
Task 4.0 Advanced ZigBee	**10/2/08**	**8/1/13**
Subtask 4.1 Interference Avoidance Technique	10/2/08	8/3/09
Milestone P241: Interference Avoidance Techniques	8/3/09	8/3/09
Subtask 4.2 Cluster-tree ZigBee Systems	8/4/09	8/3/10
Milestone P242: Cluster-tree ZigBee Systems	8/3/10	8/3/10
Subtask 4.3 MAC Layer Protocol	8/4/10	8/4/11
Milestone P243: MAC Layer Protocol	8/4/11	8/4/11
Subtask 4.4 ZigBee Installation Plan	8/5/11	8/1/12
Milestone P244: ZigBee Installation Plan	8/1/12	8/1/12
Subtask 4.5 ZigBee Pilot Demo	8/2/12	8/1/13
Milestone P245: Pilot Demo	8/1/13	8/1/13
Phase 3 Ancillary Services	**12/24/08**	**9/10/10**
Task 0.0 Revise Project Management Plan	12/24/08	12/24/08
Task 1.0 IPPSC v. 1	1/1/10	3/25/10
Milestone P31: IPPSC V1 Installed	3/25/10	3/25/10
Task 2.0 ComEd/PJM Portal	1/4/10	9/10/10
Milestone P32: Engine Start to Full Load within 10 Minutes	9/10/10	9/10/10
Phase 4 Distribution Automation	**10/1/08**	**11/30/12**
Task 0.0 Revise Project Management Plan	10/1/08	10/1/08
Task 1.0 HRDS	**1/2/09**	**11/30/12**
Milestone P41: HRDS Installed	9/29/09	9/29/09
Task 2.0 Substation Automation	**1/2/09**	**11/30/12**
Milestone P42: Substations Compatible to HRDS	7/30/09	7/30/09
Task 3.0 IPPSC v.2	9/10/12	11/30/12
Milestone P43: IPPSC V2 Installed	11/30/12	11/30/12
Phase 5 Peak Load Reduction	**9/1/11**	**5/29/13**
Task 0.0 Revise Project Management Plan	1/12/12	1/12/12
Task 1.0 Peak Load Reduction Capability	1/12/12	5/29/13
Milestone P51: Load Reduction Controller Installed	5/29/13	5/29/13
Task 2.0 IPPSC v. 3	1/2/12	6/15/12
Milestone P52: IPPSC V3 Installed	6/15/12	6/15/12
Task 3.0 Solar PV Installation	1/12/12	12/12/12
Milestone P53: Solar PV Installed	12/12/12	12/12/12
Task 4.0 UPS Installation	1/12/12	12/13/12
Milestone P54: UPS Installed at Critical Buildings	12/13/12	12/13/12
Task 5.0 Install Energy Storage Demonstration on Microgrid	9/1/11	12/20/11
Milestone P55: A Battery Storage System Commissioned	12/20/11	12/20/11
Task 6.0 Install Electric Vehicle Charging Stations	9/1/11	12/20/11
Milestone P56: Electric Vehicle Charging Stations Commissioned	12/20/11	12/20/11
Milestone DR: Demonstration DataCollection Related to the Performance and Impact of the Deployed Assets	10/1/12	10/1/13
Milestone FR: Submittal of the Draft of the Final Report	9/2/13	9/2/13
Milestone PRO: 50% Peak Load Reduction Capability	10/1/13	10/1/13



Appendix B1 – Build Metrics for IIT's Electric Distribution Assets

BUILD METRICS: Electric Distribution System Assets				
Metric	Remarks	Value		Data Collection Method
		Project	System	
DA Devices:				
Portion of System with SCADA	SCADA is only used for monitoring and some substation control (not considered DA)	0%	100%	Engineering & Planning reports indicated all substations equipped with SCADA
Portion of System with DA	DA coverage is only for the north side of the IIT campus	xy%	xy%	Engineering & Planning analysis based on total number of circuits, circuit miles, and customers
Automated Feeder Switches	Can perform fault location isolation service restoration of three loops	xx	xx	Installation Records/System software and field tests
Feeder Monitors	Installed in the substation	xx	xx	Installation Records/System software and field tests
Remote Fault Indicators	Installed in the substation	xx	xx	Installation Records/System software and field tests
Smart Relays	Installed in the three loops	xx	xx	Collected once all three loops collected
DA Communications Network	Only for the north side of the IIT campus	xx	xx	Collected once all three loops collected
DA System Features/Applications:				
Fault Location, Isolation and Service Restoration (FLISR)	Features will be employed once all three loops are completed	Yes	Yes	Distribution operations records or system software indicating the # of switching instances for maintaining reliability
Feeder Peak Load Management	Features will be employed once all three loops are completed	Yes	Yes	Only on substation level
Microgrids	Features will be employed once all three loops are completed	Yes	Yes	Only for the north side of IIT campus

Distribution Management System:				
Integration with Distributed Energy Resources	IPPSC communicates with building controllers and solar PV system	Yes	Yes	Only for Siegel Hall

Appendix B2 – Build Metrics for IIT's Distributed Energy Resources

BUILD METRICS: Distributed Energy Resources				
Metric	Remarks	Value		Data Collection Method
		Project	System	
Distributed Generation:				
Number of gas units	Project will monitor existing DER on the system. Metrics are not related to SGDP/RDSI funding	0	2	Installation records
Total installed gas unit capacity (kW)		0	8	Installation records
Total energy delivered from gas units (kWh)		0	xxx	Meters in the power plants
Installed PV capacity (kW)	Monitor energy delivered from PV	xx	xx	Installation records
Total energy delivered from PV (kWh)		xx	xx	Meters in Siegel Hall
Energy Storage:				
Installed UPS capacity (kW)		xx	xx	Installation records
Installed energy storage capacity (kW)	A 250 kW battery storage system at the North Substation of IIT's Perfect Power Prototype, connected to installed loops 1, 2, and 3	xx	xx	Installation records
		kW	kW	Installation records
		kWh	kWh	Installation records
DG Interface:				
Remote control of gas units	IPPSC control	Yes	Yes	Installation records
PHEV				
Plug-in Electric Vehicle Charging Points	Three Level 2 electric vehicle charging stations and one Level 3 charging station will be installed on Loop 2. Three Level 2 electric vehicle charging stations will be installed on Loop 3.	xx	xx	Installation records

Appendix B3 – Build Metrics for IIT's Pricing Programs

BUILD METRICS: Pricing Programs				
Policy/Program	Remarks	Value		Data Collection Method
		Project	System	
Flat	Based on existing contract	xx	xx	Existing contract

Appendix C1 – Impact Metrics for IIT's AMI and Customer Systems

IMPACT METRICS: AMI and Customer Systems				
Metric	Remarks	Value		Data Analysis
		Project	System	
Metrics Related Primarily to Economic Benefits				
Hourly Customer Electricity Usage	Average hourly residential customer usage Targeted reporting dates: October 31, 2012	8760 data file	N/A	Data from ComEd
Monthly Customer Electricity Usage	Average monthly residential customer usage Targeted reporting dates: October 31, 2012	Monthly data file	N/A	Data from ComEd
Peak Load and Mix	Based on existing contracts Targeted reporting dates: October 31, 2012	xx%	No	Only on substation level
Annual Generation Cost	Targeted reporting dates: October 31, 2012	$	$	Information will be provided by energy contractors On a totalized, annual basis
Ancillary Services Cost	Targeted reporting dates: October 31, 2012	$	$	Information will be provided by energy contractors On a totalized, annual basis
Meter Operations Cost	Targeted reporting dates: October 31, 2012	$	N/A	On a totalized, annual basis
Metrics Related Primarily to Environmental Benefits				
CO2 Emissions	Targeted reporting dates: October 31, 2012	Tons	Tons	Information will be provided by energy contractors On a totalized, annual basis
Pollutant Emissions (Sox, Nox, PM-2.5)	Targeted reporting dates: October 31, 2012	Tons	tons	Information will be provided by energy contractors On a totalized, annual basis

Appendix C2 – Impact Metrics for IIT's Electric Distribution Systems

IMPACT METRICS: Electric Distribution Systems				
Metric	Remarks	Value		Data Analysis
		Project	System	
Metrics Related Primarily to Economic Benefits				
Distribution feeder or equipment overload incidents	Switching operations that relieve equipment overloading will also be recorded Targeted reporting dates: October 31, 2012	Maybe	N/A	Depend on ComEd
Distribution feeder load	8,760 hrs for feeders affected by Demand Response Targeted reporting dates: October 31, 2012	Maybe	N/A	Depend on ComEd
Deferred Distribution Capacity Investments	Targeted reporting dates: October 31, 2012	$	N/A	Depend on ComEd
Distribution Feeder Switching Operations	Targeted reporting dates: October 31, 2012	xx	N/A	Depend on ComEd
Distribution Restoration Cost	Targeted reporting dates: October 31, 2012	$	N/A	Restoration cost comparison between project and system feeders
Metrics Related Primarily to Reliability Benefits				
SAIFI	Indices will be reported in accordance with IEEE STD-1366 Targeted reporting dates: October 31, 2012	Index	N/A	Computed by IPPSC
SAIDI/CAIDI		Index	N/A	
Outage Response Time	Actual outage response will only be tracked for project circuits. An average outage response time will be estimated for the rest of the system Targeted reporting dates: October 31, 2012	Minutes	N/A	Operation records

Major Event Information	Named storms and other events excluded from standard reliability reports will be included Targeted reporting dates: October 31, 2012	Event Statistics	N/A	Operation records

Appendix C3 – Impact Metrics for IIT's Storage System

IMPACT METRICS: Storage System				
Metric	Remarks	Value		Data Analysis
		Project	System	
Annual Storage Dispatch	Targeted reporting dates: October 31, 2012	kWh	N/A	Operation records
Average Energy Storage Efficiency	Targeted reporting dates: October 31, 2012	%	N/A	Operation records
Monthly Demand Charges	Targeted reporting dates: October 31, 2012	$/kW-month	N/A	Operation records
Capacity Market Value	Reporting based on any participation in capacity markets Targeted reporting dates: October 31, 2012	YES	N/A	Operation records
Ancillary Services Price	Reporting based on activities that generate ancillary services revenue Targeted reporting dates: October 31, 2012	YES	N/A	Operation records

Appendix D – Baseline Impact Metrics for IIT's Electric Distribution Assets

BASELINE ESTIMATES FOR IMPACT METRICS: Electric Distribution Systems			
Metric	**Remarks**	**Baseline Estimate**	**Baseline Estimation Method**
Metrics Related Primarily to Economic Benefits			
Distribution Feeder Load	Targeted reporting dates: October 31, 2012	xx	Based on three year history, on substation level
Distribution Feeder Operation	Targeted reporting dates: October 31, 2012	xx	Based on three year history, on campus level
Distribution Restoration Cost	Targeted reporting dates: October 31, 2012	xx	Based on three year history, on campus level
Metrics Related Primarily to Reliability Benefits			
SAIFI	Targeted reporting dates: October 31, 2012	xx	Simulated by IPPSC
SAIDI/CAIDI	Targeted reporting dates: October 31, 2012	xx	Simulated by IPPSC
Outage Response Time	Targeted reporting dates: October 31, 2012	xx	Based on three year history, on campus level
Major Event Information	Targeted reporting dates: October 31, 2012	xx	Based on three year history, on campus level