Preliminary Plan for Working with South Korean Partners to Build a World Class Perfect Power System to Serve the IIT South Campus

Pursuing Perfect Power at IIT remains a university priority, and has already begun to shape the way we approach managing energy resources in pursuit of our education mission. As IIT meets the challenge of the Campus Sustainability Vision, to "become the most sustainable urban university in the United States", making swift, permanent reductions in energy resource use will serve as a centerpiece of that challenge. The IIT Perfect Power Prototype is a critical component of the IIT Sustainability vision. The IIT Perfect Power team is seeking a partner to provide a fully integrated Perfect Power system to serve the south campus.

The overall goal is to design and build a self-healing and efficient distribution and facility system that will not fail to meet the universities needs for perfect reliability, maximum conservation, and minimum carbon emissions. The specific project goals include:

(1) the achievement of system-wide Perfect Power and demonstration of its technological viability (through the implementation of distributed energy (DE) and advanced sensing, switching, feeder configuration and controls, IIT's electric power conditions will always meet or exceed each end user's requirements);
(2) 50% peak on-demand reduction capability when called upon by Exelon/PJM;
(3) 20% permanent peak demand reduction from the 2007 annual peak demand;
(4) deferral of 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 and the introduction of significant savings and revenue from providing ancillary services;
(6) a design that can be replicated to any microgrid;
(7) promote the Perfect Power prototype via the Galvin Electricity Initiative, Vanguard Communications (hired by GEI to promote the Initiative and IIT prototype), the website (www.galvinpower.org) and key partners.

Completing the Perfect Power system for the south campus includes the following tasks:

Scope	Specification See Page
Modern energy management and efficiency initiative including demand response capability and building automation (temperature setbacks, lighting, major loads)	2
South Campus Intelligent Self Healing Infrastructure	3
Expand natural gas fueled site generation	5
Renewable and Electric Vehicle Capability	6
Advanced Cyber Security Research	7
Master Controller Advancement Research	9

Modern Energy Management and Efficiency Initiative

The IIT facilities staff developed a detailed campus energy efficiency plan which was to be implemented in conjunction with the DOE project. Budget limitations forced the facilities department to put the tasks listed herein on hold.

Scope of Work

Task 1 – Install a Modern Utility Information Management System

Current IIT infrastructure requires that 95% of all building meters be read manually. This mechanism precludes real-time analysis and occasionally results in readings that need further confirmation or correction. In order to improve the real-time decision making of the IPPSC, the microgrid master controller, increase reliability in billing and management, and provide increased access to information for making efficiency and conservation decisions, this task will result in a modern metering system that receives, stores, and displays data in real-time.

Deliverable: Design and implementation of upgraded metering equipment and a real-time data acquisition and storage system.

Task 2 – Expanded Building Automation Systems

Currently, the IIT building management system covers approximately 40% of the campus building area and covers some of the major building systems. The current project includes interfacing with existing building controllers, but does not include expansion of the system to include more of the building area. This task will increase the coverage to nearly 80% of the campus area. Additionally, where the current project includes installation of Zigbee wireless control in one campus building, this task would expand that control to nine other buildings.

Deliverable: Implementation plan for expansion of building automation system and execution of that plan.

Task 3 – Additional Energy Efficiency

The current project focuses on implementation of infrastructure upgrades and demand reduction through on-site generation and conservation. Previous phases of the Perfect Power implementation included energy efficiency improvements that will have lasting effects on the campus operations. This task will re-examine the energy management strategy in the new environment of Perfect Power and affect major reductions in consumption without sacrificing services. These improvements will focus on electricity, but will touch all energy-consuming systems.

Deliverable: Implementation of IIT Energy Policy and Management Plan actions for energy efficiency.

Budget

Task	**# of Buildings**	**Budget**
Task 1: Metering Modernization		
Task 2: Building Automation Systems		
Task 3: Additional Energy Efficiency		
Total Budget		

South Campus Intelligent Self Healing Infrastructure

A large part of the Perfect Power Implementation at IIT is to improve the reliability of the electric infrastructure using intelligent self-healing devices. Additionally, the IIT facilities staff identified several critical electricity system components that have degraded to the point of requiring replacement. This includes the south substation, key switching stations, and cable utilized in the HRDS.

Scope of Work

Task 1 – Complete Replacement of South Substation

In order to realize the long-term reliability envisioned by Perfect Power, the south substation should be relocated into the existing power plant building. This requires all new equipment, revisions to the existing power plant, and transfer of cabling from existing substation to new location. The substation should be rebuilt using automated breakers and switches that allow for sectionalized looped system. Rough specifications are below:

- use of automated breakers and switches that will sense fault conditions and open within 1/4 cycle, simultaneously isolating the fault and allowing power to flow along a secondary feeder route.
- High speed, fault interrupting switchgear for the north and south main buses
- Automatic high speed transfer system – either at the individual building level, mid-distribution loop level, or substation level
- Multifunction directional over-current relays

Deliverable: Design and installation of new south substation.

Task 2 – Sectionalized Loops, Smart Switches, and communications for the South Campus

The currently proposed design for Perfect Power at IIT is based upon the S&C Electrics "High Reliability Distribution System" (HRDS). This design leverages a continuously energized loop feeder concept which provides a redundant electric supply to each campus building. Both feeds will be energized and supply electricity to the building, as well as being capable of carrying the entire building load. High-speed, intelligent automated switches will be installed to detect and isolate a fault without loss of power to the building.

The proposed HRDS is designed to be reliable, versatile, upgradeable, and cost-efficient. To meet the Perfect Power design criteria, the following schemes will be implemented:

- The system will use two substations in two closed-loop configurations to support load requirements as well as load equalization if a fault occurs on a feeder.
- To support new load growth, additional Vista units can be added anywhere along the loop system and will adhere to the system design without any changes in relay settings.
- The proposed design can support an additional source for future load expansion.

Feeder loop designations are based on the following projected building peak loads in order to evenly distribute power over the infrastructure and provide the most stable distribution system possible:

Deliverable: Installations of sectionalized distribution loops from the south substation. This work will also include any tunneling and cable replacement work required to meet the loads on the loops.

Task 3 – Upgrade Cables and Transformers

Cable replacement in the current DOE project budget include only locations where existing cables prevent the completion of the HRDS loops. Much of the existing campus infrastructure has surpassed its useful life. The current plan provides more information to operators in order to improve planning for cable replacements, but the budget does not cover upgrading all cables and components that have outlived their useful life. A full campus assessment will be performed to identify cables and transformers that have outlived their useful life. This equipment will be upgraded to improve reliability and efficiency. In addition, new conduit will be provided to complete several of the redundant loops.

Deliverable: Detailed campus electrical infrastructure assessment, replacement scope of work and execution of that scope.

Task 4 – Upgrade Existing Switch Stations and Expand Switch Station Capacity

Although the current project HRDS creates loops that are more reliable than the current layout, some of these loops have both sides of the loop passing through the same switch station located in failed manholes. This task will renovate existing manhole problems through both the restoration of existing conditions and the creation of some new switch stations/manholes to alleviate congestion and improve reliability.

Deliverable: Detailed manhole condition and reliability assessment, scope of work for relocation and repair, execution of the scope of work.

Task 5 – Move All Remaining Above-Ground Electrical Infrastructure Inside or Below-Ground

From the point where the existing utility feed enters the campus, most of the existing electrical infrastructure resides below-ground or inside buildings. The current project does not address those isolated areas where the infrastructure still exists above-ground. This task will identify all locations where this exposed infrastructure remains and remedy the current condition. In addition, the smart switches being installed under the DOE project will be placed in vaults to improve esthetics and provide for protection

Deliverable: Identification of existing above-ground infrastructure, design for relocation, and execution of the design.

Budget

Task	**Sitches/Vaults**	**Cable**	**Budget**
Task 1: South Substation Automation			
Task 2: South Campus Self Healing			
Loop 4	1-4 way, 2-5 way, 3-6 way	800’-#00, 3,000’-#500	
Loop 5	4-3 way, 1-6 way	385’-#350	
Loop 6	4-3 way, 1- 4 way	675’-#500	
Loop 7	2-4 way, 1-6 way	1000’-#500	
Task 2: Cable/Transformers			
Task 3: Manholes			
Task 4: Infrastructure			
Total Budget			

Expanded Gas Fired Clean Generation

The Perfect Power System (PPS) design included redundant site generation to ensure power to all facilities when ComEd power is lost. Due to budget constraints, the team removed the budgets for an additional 3MW of site generation at the North substation and features to lower power restoration times.

Scope of Work

Task 1 – Building Backup Generation

Several buildings on campus already have backup generation installed and others such as the datacenter already have a suitable UPS system installed. IIT has identified five or six more buildings that have critical loads requiring backup generation. Backup generation totaling 2,000 kW will be added to these buildings under this task.

Deliverable: Install 2,000 kW of Backup Generation

Task 2 – Substation Backup Generation

Backup substation generation at the south substation was identified as an important strategy for backup of the IIT campus in the event of a grid outage. The existing turbine are not large enough to support the entire campus load during outages and the backup generators will only serve part of the campus load during outages. A large number of the backup generators are diesel and have a limited fuel supply. 4MW of natural gas engine generators will be installed and connected to the main bus in the south substation and will feed the loops for that substation. The substation level backup generators can also be used to generate revenue in demand response and capacity markets to help offset their costs.

Deliverable: Installed 4M of substation level backup generation.

Task 3 – Turbine Automation

The turbines have been modified for quicker starts, but more effort is needed to automate the turbines and get them in a more dependable working order. The turbines are up for hot section overhauls, a gearbox overhaul and possibly needs a new de-ionization system. Additionally, the system is not completely setup for automated starting. The team will also look into changing the air permit to allow the turbines to be operated briefly without water injection so that the turbines do not have to wait for the water injection system to come online before starting. This can be a problem with unexpected outages which currently may require several hours to polish the water before starting.

Deliverable: Complete turbine auto start and control modifications

Task 4 – Uninterruptable Power Supply

A UPS can be coordinated with generators to carry system load for more than 120 seconds - this would be coordinated with IIT's substation generators. The UPS would instantly assume the load during an outage event and supply ride-through power until the generators are up and synchronized. The UPS can utilize either flywheel or battery technology depending on the application. The Perfect Power prototype will utilize flywheels for loads where a small UPS footprint is necessary.

Deliverable: Install 4,000 kW of UPS in coordination local backup generation

Budget

Task	Amount	Budget
Task 1: Building Backup Generation	2,000 kW	
Task 2: Substation Backup Generation	4,000 kW	
Task 3: Turbine Automation		
Task 4: UPS	4,000 kW	
Total Budget		

Solar PV, Storage, Vehicle Charging and Plug-in Vehicle Capability

The Perfect Power design called for the expanded use of solar power and electricity storage. However, budget constraints limited IIT capability to deploy both. This task would provide for campus wide deployment of solar photovoltaic (PV) and electricity storage to further reduce peak demand.

Scope of Work

Task 1 – Expand Renewable Generation (Solar PV) Integration

The current DOE budget only allows for a 20 kW solar PV array installation on the roof of Siegel Hall. However, to integrate solar PV renewable generation with plug-in hybrid electric vehicles and pure electric vehicles, five 50 kW of solar PV installation is required.

Deliverable: Installation of larger 50 kW solar PV array.

Task 2 – Incorporate Energy Storage and Electric Vehicle Charging Station

To match the generation capability of solar PV with the load demand of a commercial building, an energy storage reservoir is required. In addition, the renewable energy produced by the solar PV array can be used to charge electrified vehicles. This task will incorporate the storage system and the vehicle charging system into the Siegel Hall building integrated power system.

Deliverable: Installation of 2,000kWh energy storage system and electric vehicle charging station.

Task 3 – Incorporate Vehicle-to-Grid (V2G) Services into IIT's Perfect Power System

In addition to charging electric vehicles from the Siegel Hall building integrated power system, it is possible to use the charging station interface in the reverse direction. Electric vehicles, with their energy storage capabilities, can help support the power grid through vehicle-to-grid (V2G) technology. This task will incorporate V2G equipment and services into IIT's Perfect Power System.

Deliverable: Installation of Vehicle-to-Grid two-way meter and accounting software.

Budget

Task	**Scope**	**Budget**
Task 1: Expand Solar PV Integration	300 kW	
Task 2: Storage & Electric Vehicle Charging	2,000 kWh	
Task 3: Vehicle-to-Grid System		
Total Budget		

Advanced Cyber Security Features

Perfect Power System (PPS) needs to be protected against various communication-oriented and/or physical-compromise-oriented malicious attacks and threats[1] in addition to random faults of individual components. However, the DOE Perfect Power Project did not include security in its scope. These threats and attacks have been considered primarily for the transmission system but not for the distribution system, which traditionally does not have much intelligence.

Scope of Work

IIT will design and develop a comprehensive security treatment for the PPS and set up a software and hardware security solution framework with the following subtasks. The benefit of this work is to protect PPS from cyber attack.

Task 1 – Key Management and Authentication for Communication Security and Access Control

In PPS, message authenticity is critical, as a wrong control message initialized by the master controller could result in disastrous consequences. We propose to design and develop an efficient and attack-resilient key management that can appropriately assign keys to various system units/components so that later on these system units can securely communicate with each other.

Deliverable: Key management and authentication designs.

Task 2 – Intrusion Detection Module for Real-time System Monitoring

Intrusion detection is effective against the physical compromise oriented attacks, including disabling a selected subset of system units, compromising & controlling a selected subset of system units, and utilizing them for further attacks subsequently, etc. We will design an intrusion detection module that can monitor the system operating status in real time and detect the potential intrusion and attacks.

Deliverable: Intrusion detection module.

Task 3 – Security Enhancements for the SCADA System and DNP3 Protocol

We need to understand the current industrial security practice, identify the potential vulnerabilities and then design and develop enhanced mechanisms. Specifically, we will look into the SCADA system and DNP3 protocol.

Deliverable: Enhanced security mechanism for SCADA system and DNP3 protocol.

Task 4 – Security Enhancements for Advanced ZigBee Wireless Networks

DOE perfect power project utilizes the advanced Zigbee communication system for data collecting, system monitoring, and network controlling. Taking into consideration the characteristics of ZigBee, we plan to design and develop power-efficient, low-cost security algorithms and mechanisms to provide solutions to the vulnerabilities while balancing the tradeoffs between the security and simplicity.

Deliverable: ZigBee security software tool.

Task 5 – Validating via Simulation and Field Testing

To validate the security solutions, we adopt two approaches: simulation and field-testing. As the first effort in this subtask, we will establish an attack simulator, which simulate various attacks with respect to both communication-oriented attacks and physical-oriented attacks. The second effort is to test the security solutions resulting from the proposed research leveraging the Perfect Power System by treating the entire system as a test bed for field-testing and demonstration.

Deliverable: Attack simulator, Perfect Power System field demonstration.

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[1] These attacks can be launched by any entity with a malicious purpose and such an entity is referred to as the adversary hereafter. On the one hand, the adversary may launch communication oriented attacks against the system. For example, the adversary may (1) passively intercept the messages exchanged between the system components through either wireless eavesdropping or wired tapping, (2) actively inject forged messages or signals via a Man-in-the-middle-attack, (3) delay messages or (4) modify messages being transmitted. On the other hand, the adversary may launch physical compromise oriented attacks, including Denial of Service (DoS) attacks to disable some system components and prevent them from functioning correctly.

Budget

Task	Budget
Task 1: Key Management	
Task 2: Intrusion Detection	
Task 3: Security for SCADA and DNP3	
Task 4: Security for ZigBee	
Task 5: Field Testing	
Total Budget	

Master Controller Advancements

The site master controller capabilities were scaled back during the proposal development phase due to budget limitations and further scaled back after the DOE grant award due to increased cost for designing and building the HRDS loops. The capabilities that will be added are summarized below.

Scope of Work

Task 1 – Expand Modeling Accuracy and Fault Diagnostic Capabilities

The current DOE budget only allows for one or two state modeling methods to be incorporated into the master controller. The accuracy of the master controller can be improved by adding additional modeling methods. These modeling methods will also be used for state estimation and advanced fault diagnostics.

Deliverable: Modified IPPSC specification and IPPSC software upgrades incorporating these changes.

Task 2 –Incorporate Latest Smart Grid and Security Protocols

The communication between the IPPSC agents and elements will be based on simple XML technology in the first release. In the meantime, SmartGrid communication standards and protocols are being developed by various agencies such as NIST and IEEE. New security protocols are also being developed. This task will incorporate these new protocols into the IPPSC software.

Deliverable: Modified IPPSC specification and IPPSC software upgrades incorporating these changes.

Task 3 – Incorporate Remote Interface

This task include the effort required to develop a remote user interface for the IPPSC, so the IPPSC user interface can be accessed securely from remote computers and web enabled handheld devices.

Task 4 – Incorporate Microgrid Synchronization Coordination

In order for distributed backup generators to synchronize when the campus is an island mode, special controls are needed. The most expeditious approach to controlling synchronization is to use an inverter between the engine and building load and have the master controller send synchronization commands and signals to inverters. This task will require a certain amount of R&D before it can be completed.

Budget

Task	**Budget**
Task 1: Expand Modeling and Diagnostics	
Task 2: SmartGrid and Security Protocols	
Task 3: SmartGrid and Security Protocols	
Task 4: Synchronization Coordination	
Total Budget	

Note: Inverter costs are included in the backup power generation cost estimates.