The Illinois Institute of Technology Perfect Power System Prototype

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Abstract

The Galvin Electricity Initiative is undertaking the task of demonstrating and open sourcing an improved design for the delivery of electric power. By applying continuous improvement methods to the elements of the United States power grid, the Initiative hopes to achieve the universal adoption of a system design that successfully meets the power needs of every consumer.

Currently at a "tipping point" in its need for a more efficient and reliable electric power system, the Illinois Institute of Technology (IIT) collaborated with the Galvin Electricity Initiative, S&C Electric, Endurant Energy and Commonwealth Edison (ComEd) to explore system renewal. The team utilized quality principals to design a prototype "Perfect Power" system for the IIT campus. The prototype will demonstrate that cost-effective electric power can be delivered to the consumer precisely as that consumer requires it, without failure and without increasing costs.

The Initiative's Perfect Power model includes the following elements:

- Redundant transmission and distribution supply
- Self-sustaining infrastructure
- Intelligent distribution system and system controllers
- On-site electricity production
- Demand response capability (temperature setbacks, lighting, major loads)
- Sustainable energy systems and green buildings/complexes
- Technology-ready infrastructure

1. INTRODUCTION

In 2005, former Motorola CEO Robert W. Galvin founded The Galvin Electricity Initiative, assembling a team of top power innovation leaders and challenging them to apply Six Sigma® quality principles to the problem of electric power quality and reliability.

The Initiative is leading a campaign to develop a pathway for entrepreneurs and utilities to transform today's power system into one that cannot fail the customer – The Perfect Power System. The Perfect Power System is reliable, secure, efficient, and customer-focused. It is tailored to each end-user so it meets their needs perfectly. The Perfect Power System incorporates smart microgrids and control technology, distributed generation, combined heat and power, and renewables.

In January of 2006, the Illinois Institute of Technology and Commonwealth Edison agreed to work with the Galvin Electricity Initiative to develop the first Perfect Power System prototype at IIT. Mr. Galvin's close relationship with the school and ComEd CEO John Rowe's current chairmanship of the board of trustees made IIT a logical choice. In addition, IIT meets several criteria that make it an ideal pilot site for a next-generation power system:

- It is located within the PJM independent service operator territory with access to real time pricing;
- It owns its electric distribution system; and
- It has a robust electrical engineering program.

IIT, Commonwealth Edison (ComEd), the Galvin Electricity Initiative, S&C Electric and Endurant Energy collaborated on the Perfect Power Prototype. This collaboration is a model for bringing stakeholders together to find "win-win" solutions that benefit both customers and the greater power grid.

2. IIT'S EXISTING POWER SYSTEM

IIT's current power system relies on an aging infrastructure that is not fully meeting its current demand and will become increasingly challenged as the university grows. IIT is presently experiencing an average of three outages per year. These outages disrupt classes, destroy key experiments, damage equipment, and force staff to schedule experiments for the evening to minimize risks..

IIT's present peak load is approximately 10MW, drawing its utility power from a single ComEd area substation. Its 8 MW of on-site gas turbine cogeneration was placed in

standby mode in late 1990 in response to a favorable load retention rate offered by ComEd..

The campus distribution system employs redundant building feeds and the campus load is divided between two substations, north and south. . Switching is manual and fault detection is non-existent. In the event of an outage, considerable time is taken in identifying the fault location and in reconfiguring the system to bring buildings back online. In addition, manual reconfiguring has led to cable damage and personnel safety issues.

The typical campus building distribution system consists of two manually-switched 4.16kV feeds from a single substation with manual backfeed capability to the other substation. Power is then distributed to a number of panels on each floor where loads including lighting, fan, computer, and in many cases, window unit AC loads are served. Heating is supplied by the school's current high-pressure steam system.

IIT has deployed over 2MW of standby generation to date and will continue to add local electricity generation, UPS, and demand response capability. This will aid IIT in its drive to increase reliability and to manage energy costs and will supplement existing plans to increase campus energy efficiency. IIT is in the middle of a campus wide upgrade of windows, lighting, and heating systems aimed at lowering IIT's costs and carbon footprint.

3. ANALYZING IIT'S SYSTEM NEEDS AND FAILURE MODES

The Galvin Electricity Initiative applied Six Sigma quality principals to IIT's power system with special focus on the failure modes and effects analysis (FMEA). The team identified each point in the system that is likely to break down (failure modes), tracked the effect of each possible failure and prioritized it based on a scale of severity and probability. Failure modes with both a high probability and severity would be addressed though design changes and replacement while those scoring low can be resolved through detection and mitigation.

4. THE PERFECT POWER SYSTEM DESIGN

IIT's system design features built-in redundancies, intelligent technology, a master controller system, on-site generation, and demand-response capabilities – all key characteristics of a Perfect Power System. The paragraphs below describe how these components will be integrated into the system.

4.1 Redundant Transmission and Area Substation Supply

Background: Since 2003's great Northeast blackout, considerable attention has been paid to updating and automating transmission functionality and controls. The achievement of redundant or self-healing transmission supply to an area substation provides the most important step in stabilizing an area's power reliability. This highly motivated work, which is ongoing with significant federal backing, allowed the team to focus our efforts below the area substation level.

What it will look like at IIT: Prior to the Galvin Electricity Initative IIT and ComEd were pursuing a redundant power feed from a second ComEd substation to a new east campus. However, the need for an east campus substation will likely be eliminated by redundancies achieved through Perfect Power System upgrades.

4.2 Self -Sustaining Infrastructure

Background: Self-sustaining electric infrastructure is crucial for the success of a Perfect Power System. The many factors that can negatively impact power supply must be mitigated automatically by the system if outages are to be avoided.

What it will look like at IIT: An intelligent distribution system, coupled with on-site generation, demand response capability, intelligent controls and sustainable building technology will combine to achieve a true self-sustaining or self-healing electric infrastructure at IIT.

4.3 Intelligent Distribution System

Background: An intelligent distribution system consists of properly-sized cable and transformers capable of carrying the full expected load; feeder redundancy to offer an alternate power supply to buildings where power has been interrupted; automated breakers and switches to execute the split-second isolation of faults; automated restoration; and a communications system capable of orchestrating this split-second reconfiguration of the system.

What it will look like at IIT: IIT's Perfect Power System model will build upon S&C Electric's High Reliability Distribution System (HRDS) concept. The team separated the campus into logical groups of buildings that will each be placed on a feeder loop. Each loop will be continuously energized. In the event of a loss of one section of cable or a switch, the design concept provides for the automatic isolation of faults without interruption of power to any loads. Re-closure is not necessary, but is available.

This system loop configuration is made effective by the use of intelligent switching and breaker coordination technology which provides for rapid assessment and isolation of faults via advanced communications.

4.4 On-Site Electricity Generation

Background: Generating electricity onsite is a key component of Perfect Power in situations where redundant utility distribution is unavailable or power reliability requirements exceed the grid capability, . Reliability is

increased in the form of electricity storage, UPS, back-up generation, and continuous generation. In addition, on generation can reduce energy costs by offsetting peak electricity pricing or mitigating the risks of purchasing electricity in real time.

What it will look like at IIT: The team plans to supplement the 8 MW of gas turbine generation with two 2MW gas engine generators at the substation level. This generation, in concert with building or load-specific uninterruptible power supply (UPS) will be able to carry all of the campus's critical loads in the event of a loss of utility power. In the rare cases where HRDS and substation-level generation will not provide Perfect Power System reliability, building-integrated power systems or load-specific generation will be employed.

4.5 Demand-Response Capability

Background: Utilities compensate customers who can alleviate stress on the grid due to peak demand conditions. The ability to respond to the utility's need to reduce demand on the grid is not only a source of revenue but is critical to Perfect Power beyond the customer site level.

What it will look like at IIT: Demand-response control will be integrated into the campus in two ways. In some cases, building circuits can be switched off by the HRDS controller. For more flexibility and precision, additional load controllers will be installed on certain loads and circuits for demand-response control. The loads will be operated by a demand-response load controller.

4.6 Intelligent Perfect Power System Control

Background: In order to function correctly, Perfect Power Systems require sophisticated monitoring, communication and supervisory control capability. A master controller is built into each system to monitor and trend critical parameters and determine the system state. It then changes system operating conditions to maintain the system within the specified limits of operation.

What it will look like at IIT: At IIT, the Intelligent Perfect Power System Control (IPPSC) will:

- Start and stop local generators and storage devices;
- Control local loads based on predetermined sequence of operation and load reduction priority schemes;
- Automatically switch loads to alternate transformers, campus feeds and substations as required by conditions; and

Place a building or the entire campus in island mode.

4.7 Sustainable/Green Building Technology Capability

The Perfect Power System will help IIT achieve its sustainability goals by reducing pollutant and carbon emissions through energy conservation, leveraging renewable resources, and reducing peak demand that strains the distribution system and increases energy costs. This includes energy efficiency upgrades, efficient hot water loops for building clusters, building envelope improvements, and advanced building controls.

5. BENEFITS OF PERFECT POWER FOR IIT

The proposed Perfect Power System prototype addresses a number of existing and future campus needs. The campus is outgrowing the electrical distribution system described above in several areas and critical components are reaching their end of life. The prototype provides an opportunity to replace worn-out components while applying the Perfect Power System design in such a way as to eliminate extended outages at the campus.

5.1 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.

5.2 Reduced Energy Costs

IIT and ComEd are located in the Pennsylvania, New Jersey, Maryland (PJM) Independent System Operator (ISO). This provides for the opportunity to purchase electricity in real time. 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 site generation to cap the electricity price.

5.3 Improved Reliability

The Perfect Power System 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 site generation will be expanded from 8 to 12 MW to carry the entire campus 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 have Uninterruptible Power Sources locally.

5.4 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.

5.5 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. Implementation of the 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 million per year due to the added campus features and functions.

6. CONCLUSION

The IIT prototype provides a glimpse of a new electricity system paradigm where utilities and customers work together to build local Perfect Power systems that serve both the customer and the greater power grid to bolster reliability and efficiency across the entire U.S. power system.

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.

Biography

John F. Kelly is currently for the Vice President of Technology Solutions at Endurant Energy, an energy technology services firm developing sustainable energy systems for buildings, major land developmetns, and cities across the United States. Mr. Kelly is currently leading a team of experts in the development of a "perfect power" or sustainable energy system for the Illinois Institute of Technology campus and the Hudson Yards development in New York City. Prior to joining Endurant, Mr. Kelly was the Director of Distributed Energy Technologies for the Gas Technology Institute in Des Plaines, Illinois, where Mr. Kelly established GTI's Sustainable Energy Planning Office.

Don Von Dollen is the Program Manager for the Electric Power Research Institute (EPRI) Communications and Data Integration Group and the leads the IntelliGrid Program. The IntelliGrid Program is focused on accelerating the transformation of the power delivery infrastructure into the intelligent grid needed to support our future society through a unique collaboration of public and private stakeholders. Mr. Von Dollen joined EPRI in 1991 and has held positions as Applications Manager for Power Delivery and Markets, Program Manager for Underground Transmission and Project Manager. Mr. Von Dollen has managed EPRI's superconductivity research program including wire and cable development, and research projects relating to transmission cable systems.