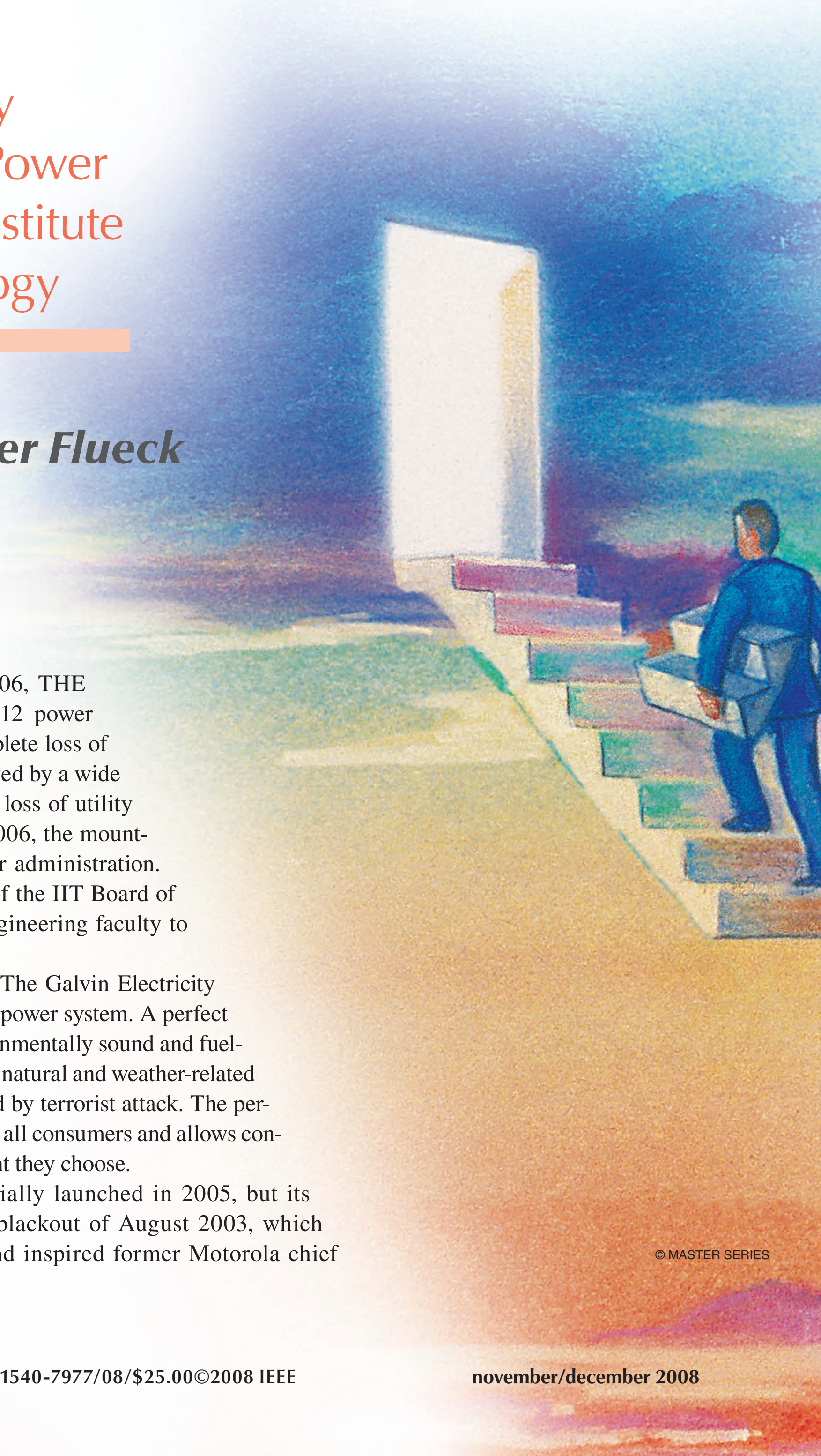
Destination: Perfection

The Journey to Perfect Power at Illinois Institute of Technology

By Alexander Flueck and Zuyi Li



IN THE THREE-YEAR PERIOD OF 2004–2006, THE Illinois Institute of Technology (IIT) suffered 12 power outages ranging from partial loss of load to complete loss of load on the main campus. The outages were sparked by a wide variety of root causes including partial and total loss of utility supply and contractor error. By the summer of 2006, the mounting costs had received the attention of the senior administration. Coincidentally, Robert W. Galvin, former chair of the IIT Board of Trustees, extended an invitation to the power engineering faculty to join the Galvin Electricity Initiative (GEI).

According to the GalvinPower.org Web site, "The Galvin Electricity Initiative is leading a campaign to create a perfect power system. A perfect power system cannot fail the consumer. It is environmentally sound and fuel-efficient. It is robust and resilient; able to withstand natural and weather-related disasters and mitigate the potential damage caused by terrorist attack. The perfect power system provides affordable electricity to all consumers and allows consumers to control their own energy use to the extent they choose.

"The Galvin Electricity Initiative was officially launched in 2005, but its genesis dates back to the massive East Coast blackout of August 2003, which left nearly 50 million people without power and inspired former Motorola chief

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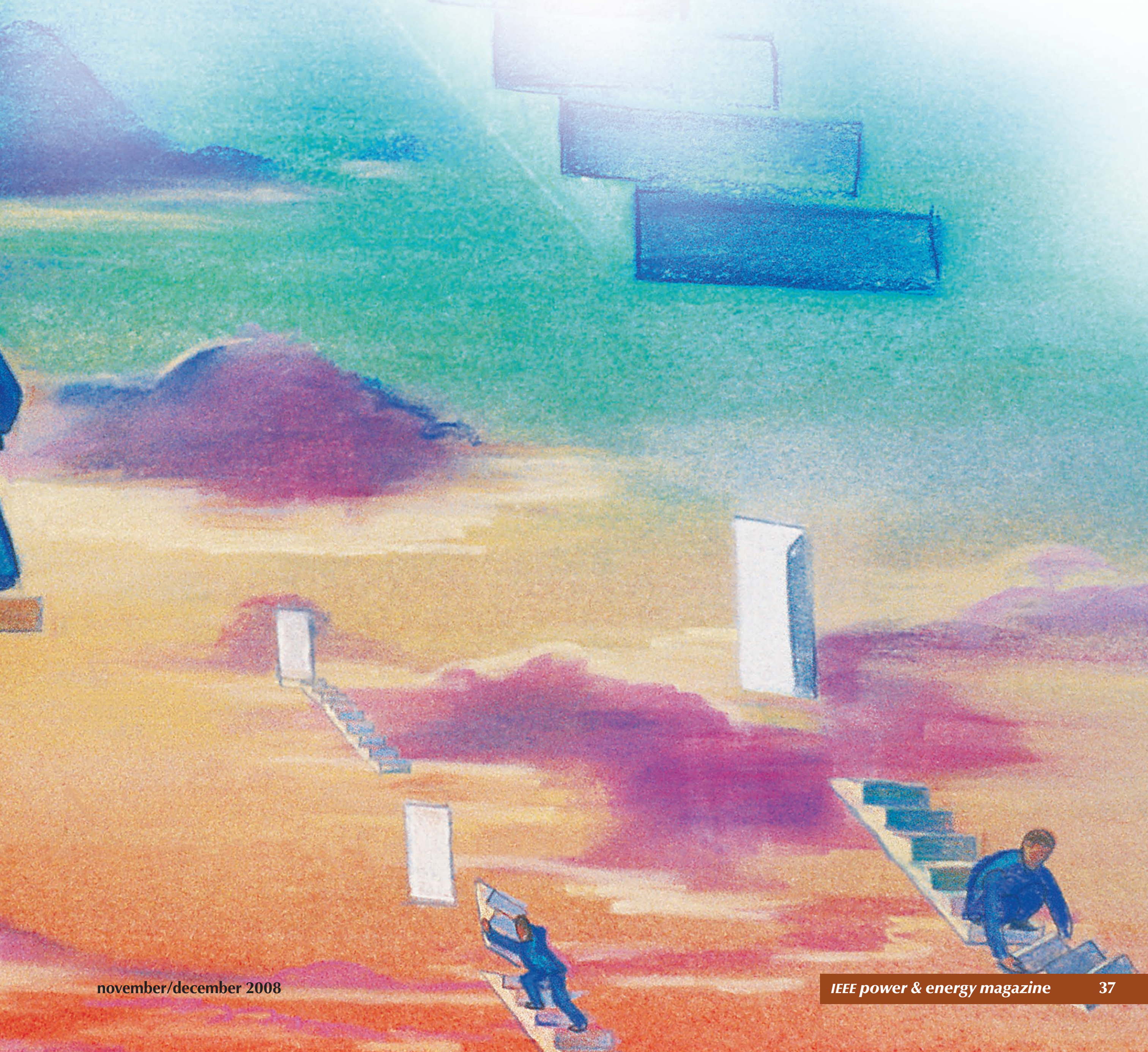
Robert W. Galvin to take action." Galvin is known throughout the business and technology communities for his dedication and leadership in quality improvement. Perfection is the ultimate goal of any quality improvement process, hence the term perfect power was born.

IIT has begun its journey to perfect power. The destination of perfect power may be far off in the distance and the exact implementation route may be unclear, but the concept is straightforward and compelling. The goal of the Perfect Power Project at IIT is to have a power system that never fails the consumer. The power failures at IIT during 2004–2006 disrupted classes, destroyed some short-duration and long-duration experiments, and damaged equipment. In addition, power quality problems at IIT have forced research faculty and staff to schedule sensitive experiments in the evening to minimize disruption and contamination risks.

You might be asking yourself, "What price is the consumer willing to pay for such a power system?" That question is critical to the approach that IIT will take toward perfect power. Clearly, the consumer must shift from a largely passive end user to a more active power user. Consumers must have choices so that they can balance their energy use and their costs.



> Transforming the IIT power delivery infrastructure to achieve perfect power is a bold idea that will require a never-ending series of innovations.

At this point, it is important to point out that improving the quality of the power delivery system does not necessarily require more resources. In many cases, improving quality leads to lower costs. One issue that is typically overlooked in economic analyses of a power delivery system is the cost of outages. In one of the IIT outages, contractor error led to a blackout of several student dormitories. The subsequent hotel costs for students during a holiday break were substantial, not to mention the equipment damage and the lost productivity costs as IIT staff managed the crisis.

Of course, individual components will fail in the future, so the Perfect Power Project at IIT will create a power system that is robust and resilient with the ability to reconfigure itself automatically following a disturbance. In addition, the future IIT power system will integrate renewable energy sources, storage and distributed generation.

During the summer of 2007, IIT joined forces with several key organizations in the electric power industry and submitted a proposal to the Department of Energy (DOE) Renewable and Distributed Systems Integration Funding Opportunity within the R&D Division of the Office of Electricity Delivery and Energy Reliability. The goal of the program is "[to] demonstrate peak load reduction on distribution feeders with the implementation of distributed energy and energy management systems at a cost competitive with system/capacity upgrades."

The team includes IIT (lead organization), Exelon/Commonwealth Edison Company (ComEd), S&C Electric Company, Endurant Energy, Integrys, the GEI, and other power industry experts. An important aspect of the proposed DOE project will be to enhance on-site peaking capacity resources. Distributed resources can reduce peak demand, which can eliminate or defer new transmission and distribution capacity, and decrease electricity prices. Enhanced on-site peaking generation resources also improve reliability and security.

To chart a course toward our destination of perfection, the multidisciplinary team has focused on the following necessary components of a perfect power system:

- ✔ real-time reconfiguration of power supply assets
- ✔ real-time islanding of critical loads
- ✔ real-time optimization of power supply resources.

In addition, the team is investigating the real-time power market participation opportunities for the two 4-MW Allison gas-fired turbines located on campus.

IIT, in conjunction with the GEI and ComEd, used quality principles to design a prototype "perfect power" system for the IIT campus. This first step toward perfect power will provide a glimpse into the future of electricity. The prototype will demonstrate that cost-effective electric power can be delivered to the consumer precisely as the consumer requires it without fail.

The objectives of the Perfect Power Project include: 1) the achievement of system-wide perfect power and demonstration of its technological viability; 2) 50% peak demand reduction capability via on-site generation when called upon by ComEd/PJM; 3) deferral of ComEd planned substation upgrades due to the demand reduction achieved; 4) 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; and 5) a design that can be replicated to any municipality-sized system where customers can participate in electric power market opportunities.

The perfect power model includes the following elements:

- ✔ redundant transmission supply
- ✔ redundant area substation supply
- ✔ self-sustaining infrastructure
- ✔ intelligent distribution system
- ✔ on-site electricity production
- ✔ demand response capability (A/C, lighting, major loads)
- ✔ intelligent perfect power system controller (IPPSC)
- ✔ sustainable energy systems and green buildings/complexes
- ✔ technology-ready infrastructure.

The perfect power prototype at IIT does not include redundant transmission or area substation supply at this time. Instead, local generation on campus and uninterruptible power supply (UPS)/backup generation at key facilities ensure that the campus can run independent of the utility or to backup the grid and provide ancillary services.

The perfect power prototype builds upon the high reliability distribution system (HRDS) design developed by S&C Electric, which is a loop system that provides high reliability service to each building. In this system any single fault on any of the feeder loops can be isolated without interrupting power. In addition, the perfect power prototype will include an IPPSC to manage the campus electricity distribution and usage. This includes coordinating with ComEd and the PJM ISO to provide ancillary services and demand response.

Fortunately IIT is located in the PJM ISO where ancillary services are valued at roughly US$10,000–$20,000/

MW/year. In addition, IIT can participate in real-time pricing, which will reduce annual electricity costs by up to US$1 million. IIT will utilize the local generation and demand response capability to mitigate the 500–1,500 hours a year of high-cost electricity.

IIT and the PJM ISO provide 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.

The Present Energy System at IIT

The project began with the assessment of present conditions at IIT. The IIT energy system can be divided into the following major subsystems. This section details the existing conditions found in each of the following subsystems:

- ✔ area substation supply
- ✔ campus distribution
- ✔ building distribution
- ✔ backup power
- ✔ energy procurement
- ✔ energy sustainability.

Area Substation Supply

IIT load is supplied by three separate 12.47-kV circuits fed from the Fisk Substation. Three 12.47-kV circuits supply the South Substation and two 12.47-kV circuits supply the North Substation (Figure 1).

- ✔ To the South Substation, all circuits run entirely underground from inside the Fisk Substation to the transformers inside the IIT South Substation. Note that one circuit also connects to Pershing, but Pershing only connects load, no supply.
- ✔ To the North Substation, one of the circuits runs above ground approximately 2,000 feet between the South Substation and the North Substation. In addition, both circuits connect to outdoor transformers next to the North Substation.

Each 12.47-kV circuit is rated at 7 MW. The highest peak load at IIT in the last two years was approximately 10 MW. Since the system is designed to supply IIT with any one of the three circuits out of service, the utility supply system has a maximum rating of 1MW.

Campus Distribution System

The IIT 4,160-V campus distribution system consists of the ComEd secondary circuits from the 12.47/4.16-kV transformers, supply breakers, a north and a south substation, feeder breakers, multiple building feeder cables (all underground), transformer supply breakers, and building transformers (Figure 2). Most of the IIT buildings have redundant feeds and the majority of these can achieve some level of IIT 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, which limits their ability to serve as backup feeders. Recently, some cable has been upgraded to 15 kV.

Building a Distribution System

The IIT perfect power team selected Siegel Hall as the pilot building for deployment of the perfect power system. Beginning implementation at the home of the Electrical and Computer Engineering Department will offer IIT students the educational benefit of experiencing the perfect power principles first hand and could afford the GEI access to valuable research resources in the form of joint research projects. While there is hardly a "typical" IIT building, Siegel Hall encompasses many of the infrastructure hurdles the initiative is working to surmount; e.g., inefficient windows, inefficient heating/cooling, inefficient lighting, and many sensitive loads.

The Siegel Hall distribution supply system (Figure 3) consists of two 4.16-kV feeds from the North Substation. Feeders 12 (primary) and 11 (secondary) provide feeder redundancy through manual switches 176 and 177, respectively, which feed into a 500-kVA transformer where power is stepped down to 240 V. Power is then distributed to two panels on each of the three floors where loads including heating, ventilation and cooling (HVAC), lighting, and computer loads are served. Several rooftop and window A/C units are supplied from these panels but the vast majority of heating is supplied by the current high-pressure steam system.

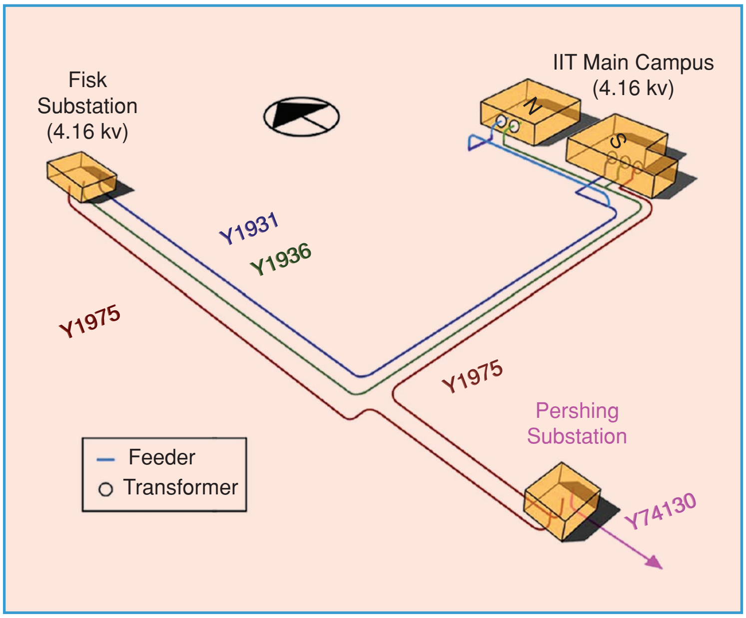


figure 1. ComEd supply to IIT.

> The prototype will demonstrate that cost-effective electric power can be delivered to the consumer precisely as the consumer requires it without fail.

Backup Power

IIT has deployed over 2 MW of standby generation to date and will continue to add local electricity generation and storage to provide for backup, UPS, and demand response capability.

Energy Procurement

IIT is seeking to manage energy costs by leveraging the perfect power system, local generation, and demand response. This will be accomplished through improved energy efficiency, reduced outages and interruptions, real-time pricing, and working with ComEd/PJM to provide ancillary services and support.

Energy Sustainability

IIT is committed to reducing carbon emissions from energy use. Carbon dioxide is produced when fossil fuels are burned to produce electricity, steam heat, and hot water for the campus. IIT is in the midst of a major upgrade of the campus heating system. The installation of more efficient boilers and more efficient steam/hot water distribution systems will save money and reduce carbon emissions.

An analysis of the EPA eGRID data revealed that IIT is supplied by nuclear generation during off peak periods and coal-fired generation during on peak periods: Monday through Friday, 7:00 a.m. to 10:00 p.m. With coal-fired generation producing about 2,300 lb of CO_2 for each megawatt hour of energy supplied, the on-peak energy consumption at IIT results in 25,000 metric tons of CO_2 emissions annually.

In order to slow growth in their electricity demand, IIT has embarked on a major building energy efficiency upgrade program that includes advanced lighting, new windows, and new chillers. However, due to extensive recommissioning of existing buildings and planned new construction, on-peak consumption is still expected to increase 9 million kWh over the next ten to 15 years.

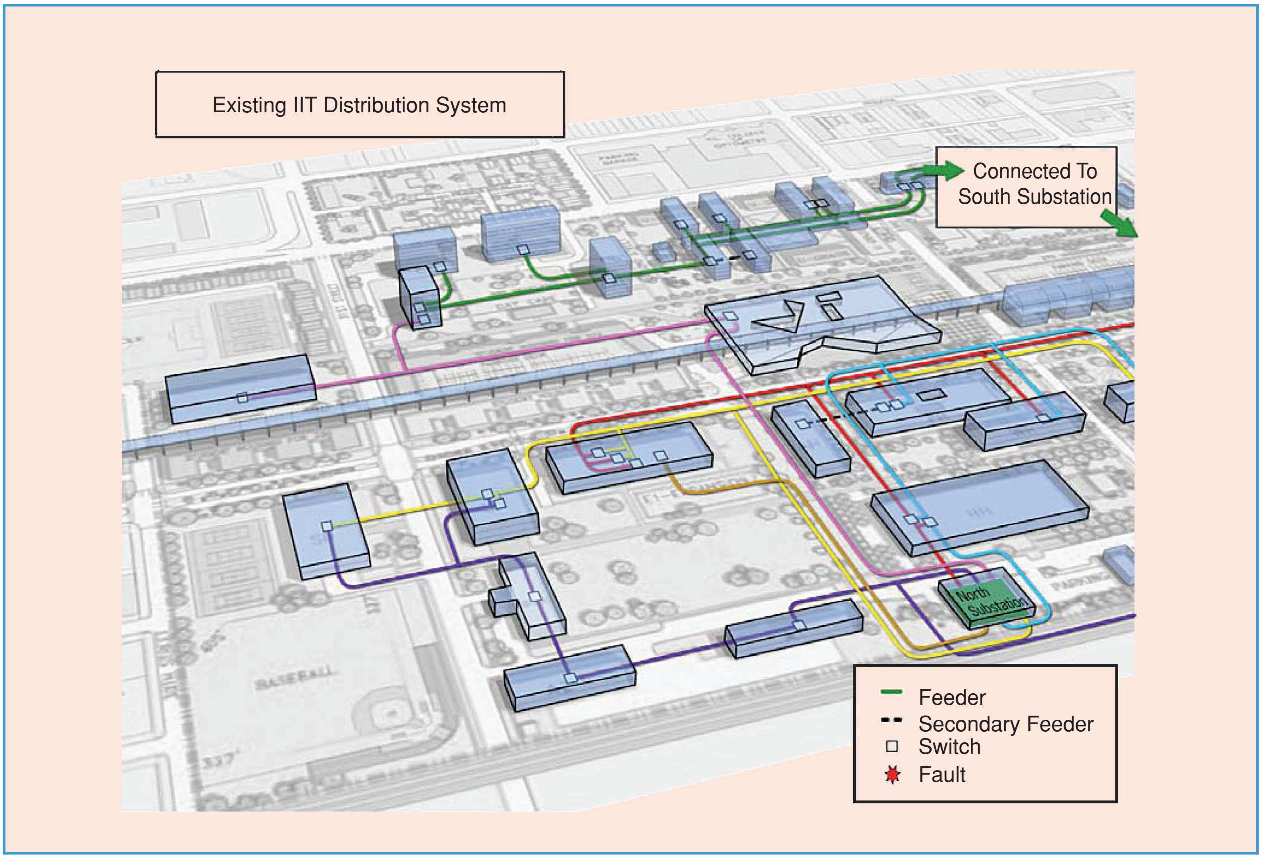


figure 2. Campus distribution system.

Further carbon reductions can be achieved through the procurement of electricity from renewable sources or from the use of on-site renewable, geothermal, or biofuel/gaseous fuel-fired generation.

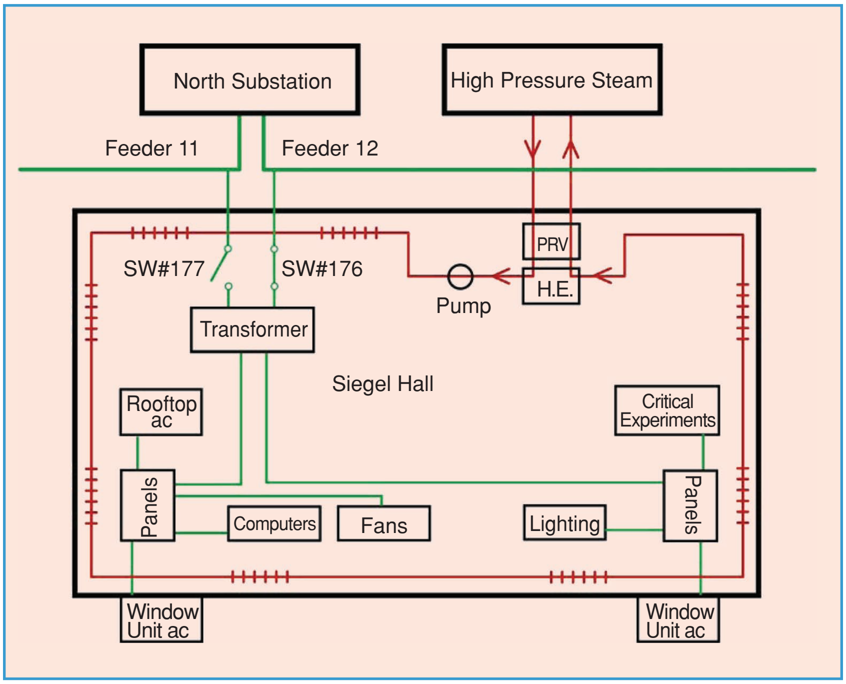


figure 3. Siegel Hall distribution system.

Analysis of System Needs and Failure Modes

The IIT Perfect Power team applied six-sigma quality principles in the development of the perfect power system. The team also conducted a detailed failure modes and effects analysis (FMEA). Each failure mode was evaluated to determine its severity and probability. The combination of probability and severity was utilized to determine the type of solution to pursue. The higher impact failure modes will be addressed through an infrastructure design change aimed at eliminating the failure mode. The lower impact failure modes will be resolved through a detection process and a postevent corrective action. To allocate resources efficiently, the team will evaluate the lower impact failure modes as their relative frequency becomes known. In this way, the project will use resources efficiently in the pursuit of perfection, rather than waste resources by gold plating the system.

Based on the FMEA work, the highest priority subsystems include:

- ✔ utility supply, especially if load increases to 1MW
- ✔ site distribution cables
- ✔ South Substation.

Solution: The Perfect Power Prototype

In the pursuit of perfect power, the team utilized the following GEI documents as guidance in identifying solutions for addressing energy system failure modes and IIT constituent power needs:

- ✔ Master Controller Requirements Specification for Perfect Power Systems, Revision 2, 9 November 2006
- ✔ The Path to Perfect Power: New Business Opportunities for A Customer-Demand Driven Electricity World, November 2006
- ✔ The Galvin Electricity Initiative: Task 3—Technology Scanning, Mapping and Foresight, March 2006.

The team then applied these Perfect Power elements and GEI guidelines to the IIT system to design the IIT perfect power prototype.

The IIT perfect power system model will build upon the S&C Electric HRDS concept. The team separated the campus into logical groups of buildings that will be placed on electricity and thermal loops to maximize reliability and efficiency. Each electricity loop will be continuously energized. In the event of a loss of any one section of cable or any switch, the design concept provides for the automatic isolation of faults without interruption of power to any loads. Reclosure is not necessary but is available.

This system loop configuration is made effective by the use of intelligent switching and breaker coordination technology that provides for rapid assessment and isolation of faults via advanced communications. The perfect power system will be managed by an IPPSC, which will monitor critical parameters to determine the system state and capture trends. The IPPSC will supervise various controls to maintain the system within the specified limits of operation.

The perfect power system will be backed up by on-site generation, which eventually will be sufficient to carry the entire campus load in the event of a loss of utility supply or a grid signal to provide ancillary service.

Redundant Transmission Supply

Since the 1 August 2003 Northeast blackout, considerable attention has been paid to updating and automating transmission functionality and controls. The achievement of providing redundant and self-healing transmission to an area substation provides the highest level of reliability. While reinforcing the transmission system is beyond the scope of the IIT Perfect Power Project, it is an ongoing initiative at the state and federal level, with significant federal backing, and will allow us to focus our efforts below the area substation level.

Redundant Area Substation Supply

IIT and ComEd have discussed informally the possibility of adding a power feed from the Quarry substation to a new substation on the east side of campus, which would support new housing and other campus improvements. However, the need for an east campus substation can be eliminated through the implementation of the perfect power prototype. The increased reliability, demand response capability, and the on-site generation will provide the desired redundancy, while avoiding the cost of a new substation (Figure 4). The cost of a new east substation and associated distribution supply circuits has been estimated at approximately US$5 million and US$2 million, respectively.

Below the level of redundant substation supply, the existing redundant distribution feeder circuits could be modified for greater reliability. One option is to move the remaining 12.47-kV overhead section between the IIT South and North Substations into an underground duct. Another utility improvement will provide animal protection for the two exposed transformers feeding the North Substation. Finally, preventative maintenance on the supply transformers will improve reliability of the utility distribution supply system.

IIT will continue to upgrade its distribution system by installing 15-kV rated components to move (potentially) the entire distribution system toward 12.47 kV with the benefits of lower resistive losses. This also would eliminate the need for the above ground utility transformers next to the North Substation and the indoor transformers in the South Substation, which currently step down the utility distribution voltage of 12.47 kV to the campus distribution system at 4.16 kV.

Feeder Redundancy

Feeder redundancy will allow the rerouting of power to buildings in the event of a fault on a distribution feeder. Used in concert with high-speed automated breakers and switches, redundant feeders allow for the cycle-by-cycle reconfiguration of the system to keep power flowing to all buildings.

IIT's perfect power distribution system will be based upon the HRDS (Figure 5) developed and implemented by S&C Electric for the University of California at Santa Barbara. This design leverages a continuously energized loop feeder concept that 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, upgradable, and cost efficient. The approach utilizes S&C Vista underground fault-clearing switch gear in a closed-loop system with SEL-351 directional overcurrent protection relays. Feeder loop designations were based on projected building peak loads in order to evenly distribute power over the infrastructure.

Automated Breakers and Switches

The isolation of faults will be executed by automated breakers and switches that will sense fault conditions and open within a quarter cycle, simultaneously isolating the fault and allowing power to flow along a secondary feeder route.

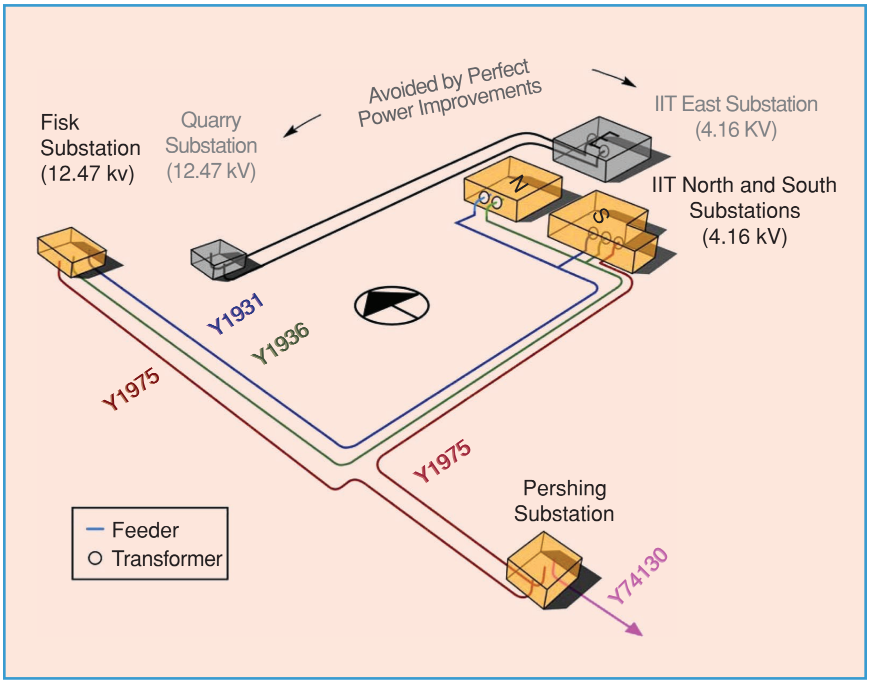


figure 4. Redundant area substation supply.

Coordinated Communications

For the system to function as a whole, to be efficient and flexible while maintaining a system-wide cohesiveness, distributed intelligence will need to be connected and coordinated. In certain fault scenarios, there will be various and competing solution strategies. The proper diagnosis of problems and often the proper *sequencing* of solution steps is crucial, so disparate intelligent parts will have to be both aware of each other and controllable by a system overseer that can orchestrate the actions of the whole system.

The IIT Perfect Power prototype will leverage the research and design capabilities of IIT and ComEd to develop an advanced power communications system. The team will explore technologies ranging from fiber optics that would follow cable conduit to highly flexible and cost-effective ZigBee wireless technology.

On-Site Electricity Generation

For sites with redundant transmission and area substation feeds, full coverage of the demand through on-site generation may not be needed to achieve acceptable levels of reliability. However, in cases such as IIT where redundant transmission and area substation feeds are not feasible or cost-effective, on-site generation increases reliability and provides for demand response. Reliability is increased in the form of back up and grid-support generation. On-site generation comes in many forms, each with its own advantages and disadvantages based on the application (Table 1). These range from load-specific back up (75–100 kW), to building back up (300–600 kW), to substation back up (2–MW), to municipal power (4–20 MW) and can encompass renewable sources and UPS flywheels and batteries.

Substation-Level Generation

The IIT perfect power team plans to install MW of distributed generation at the North Campus Substation. These gas-fired Caterpillar engines, in concert with the South Substation's 8 MW (derated to 6.5 MW during summer months)

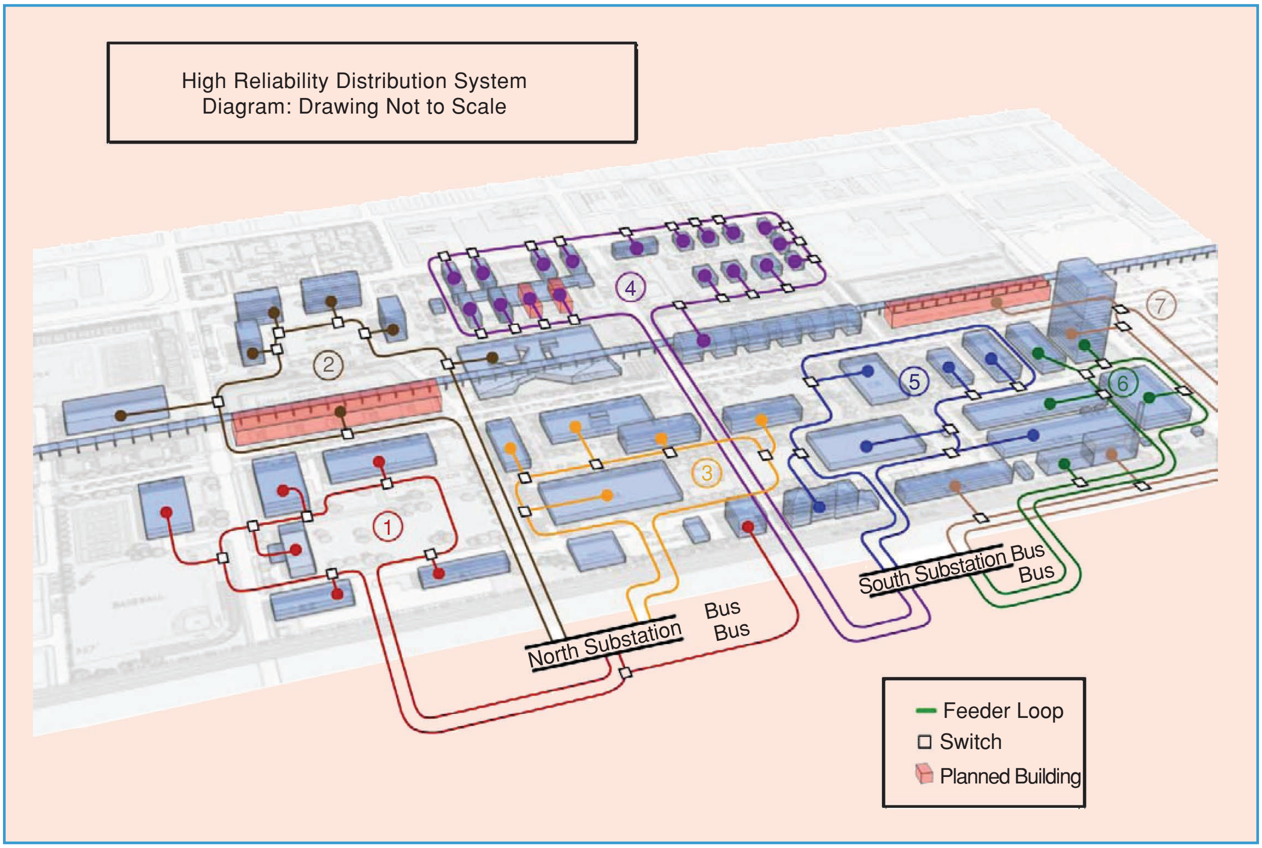


figure 5. High-reliability distribution concept.

table 1. Time response for generation options.

Option	Start Time	Discussion
Diesel-Fired Generation	10 s	Diesel generators start and load quickly; however, they do not support demand response or real-time pricing due to run-time restrictions (emissions limits and fuel storage).
Natural-Gas-Fired Generation	1 min	Longer start times; however, improved environmental performance provides for longer operation to support demand response and real-time pricing.
UPS	Instantaneous	UPS ensures that power is not interrupted; however, it typically only provides a few minutes of power and is used to transition to diesels or natural-gas-fired generation. IIT will deploy UPS as necessary to support local building perfect power needs.
This is based on 21 May 2007 meeting with Endurant Energy, IIT, and Patten Power (the local CAT dealer).		

will be capable of carrying all of the campus's critical loads in the event of a loss of the utility feed. When called upon by ComEd or PJM, these on-site generation sources will support distribution and transmission level load control programs.

Building-Integrated Energy Systems

Figure 6 provides an overview of a building-integrated energy system, which includes redundant electricity supply, efficient hot and chilled water supply, UPS and/or generation, renewable energy sources, and an advanced building control system.

In cases where an HRDS system with substation electricity generation cannot be deployed, such as on a radial distribution system, building-integrated power systems (BIPS) will provide local generation, power conditioning, and uninterruptible power ride through capability. This typically requires local generation, inverters, and electricity storage, which is integrated with the building distribution system and loads.

The BIPS system, shown in Figure 6, will include

- ✔ local building generation to carry the building load for an extended distribution system outage
- ✔ UPS/storage to provide electricity while the local generation is starting
- ✔ inverters or power quality conditioning devices
- ✔ a load controller to modulate generator output to gradually unload the UPS and to follow the building loads
- ✔ motor soft-start capability for large motor loads such as elevators
- ✔ noncritical load-shedding capabilities
- ✔ communication to the IPPSC (probably through a building-level master controller).

UPS and Electricity Storage

The UPS can be designed to carry the load of a system for up to several minutes for minor outages on a system that cannot tolerate even milliseconds without power (such as computer server loads), and as such it is an important part of a self-sustaining infrastructure. A UPS can be coordinated with generator sets to carry system load for more than several minutes. The UPS would instantly assume the load during an outage event and supply ride-through power until the generators are up and synchronized.

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.

Demand Response Capability

Demand response control will be carried out using a two-fold approach. 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.

Figure 7 shows the projected impact of IIT entering the real-time pricing and demand response markets. Based on historic data, IIT will generate 1,000–1,500 hours per year in response to the real-time markets. Demand response

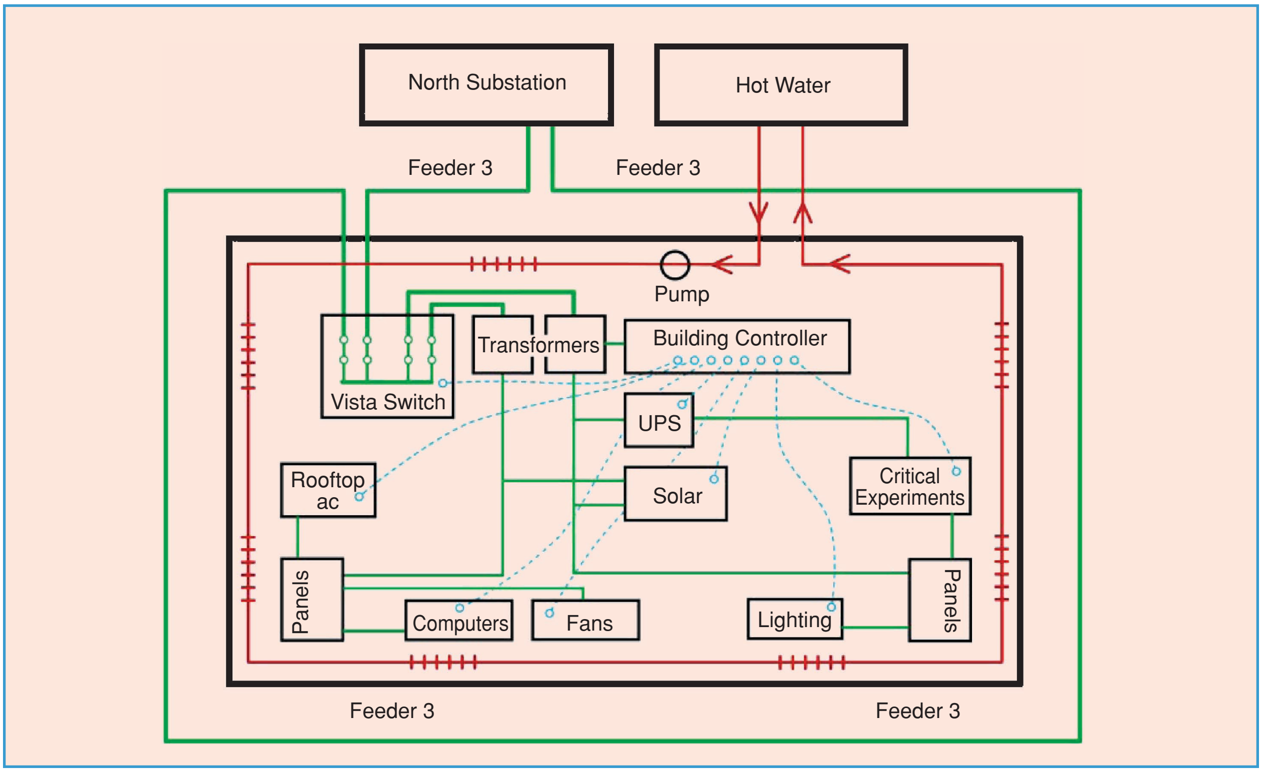


figure 6. Building-integrated energy system.

> In the event of a loss of any one section of cable or any switch, the design concept provides for the automatic isolation of faults without interruption of power to any loads.

should trim approximately another megawatt of IIT's peak demand. As IIT's load grows, the percentage reductions are expected to remain constant.

Intelligent Perfect Power System Controller

The IPPSC will be designed to optimize system performance. This includes reconfiguring the perfect power system to respond to threats and economic conditions. The IPPSC will then remotely configure the perfect power system to maintain stability.

The IPPSC, shown in Figure 8, will be an agent-based control system designed to interface with and coordinate the actions of controllers distributed around campus such as controllers for the HRDS, generation, and building controllers. The IPPSC will consist of a supervisory agent and specialized agents that will be used to interface with controllers distributed around campus. The primary role of the supervisory agent is to gather information from the outside world and determine modes of operation for the other agents distributed around campus. The specialized agent controllers are used to provide functions and decision-making ability not normally available in master controllers for generator sets, distribution systems, or building load management systems.

Some of the IPPSC's tasks will include the following:

- ✔ starting and stopping local generators and storage devices
- ✔ controlling local loads based on a predetermined sequence of operation and load reduction priority scheme
- ✔ automatic switching of loads to alternate transformers, campus feeds, and substations
- ✔ placing a building or the entire campus in island mode.

The overall site energy system control scheme will consider economic, environmental, comfort, threats, and other end-use objectives to make decisions regarding the proper operating modes and sequences. The IPPSC enables perfection by anticipating system needs and taking action to mitigate threats to system reliability and performance. The IPPSC coordinates with agent controllers to manage the safe and reliable operation of the microgrid, namely

- ✔ local generation
- ✔ storage devices
- ✔ demand response elements
- ✔ smart switch controls
- ✔ power quality devices.

The IPPSC continually evaluates both existing and possible conditions and chooses operating modes and operating conditions of local devices to maintain required reliability and power quality. This includes a dedicated SCADA system with user-friendly human-machine interface (HMI) and/or other intelligent operating systems.

Intelligent Monitoring, Trending, Detection, and Mitigation

The backbone of the perfect power system is an intelligent trending, detection, and mitigation system that collects

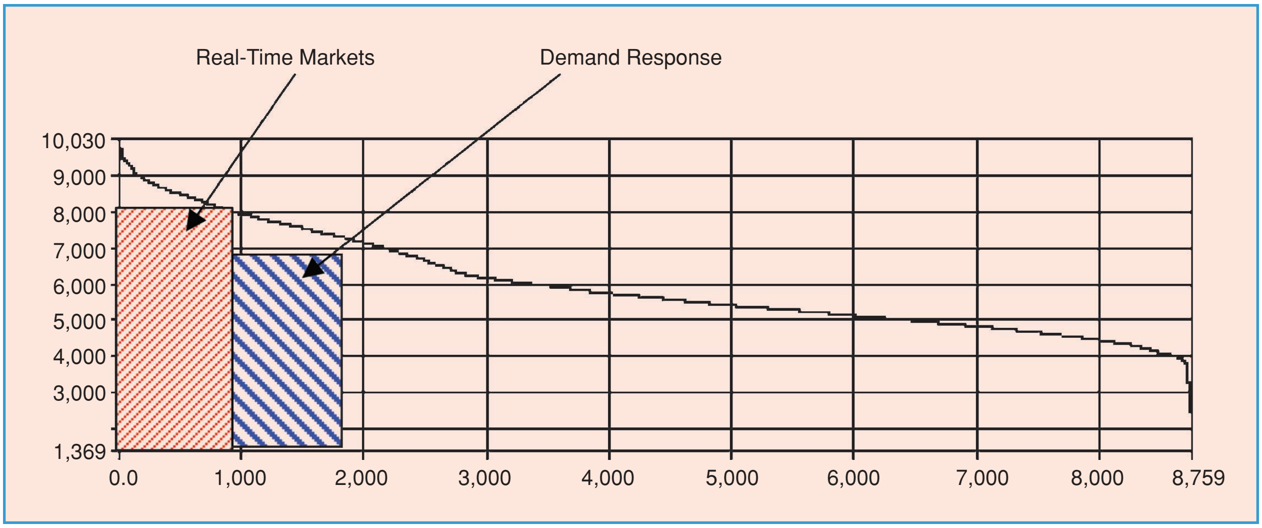


figure 7. Projected impact of entering real-time pricing and demand response markets on the current load duration curve.

thousands of inputs, trends these parameters, determines their potential impact, and changes the system operation to mitigate the consequences of adverse trends.

The monitoring and communications system includes the robust deployment of lower-cost mesh sensor and modules that communicate via a wireless and wired IP-standardized communications network. This includes:

- ✔ advanced meters at each breaker down to the main building panels that measure voltage, frequency, current, reactive power, power consumption, and harmonics as well as individual building loads (lighting, chillers, fans, and plug loads)
- ✔ weather condition and lightning sensors
- ✔ signals from the IPPSC to dispatch generation based on PJM real-time pricing signals for electricity and natural gas projections
- ✔ local generation and storage output levels, storage capacity, and fuel supply status.

Some of the important trending functions include:

- ✔ power versus frequency curves
- ✔ voltage versus reactive power curves
- ✔ power quality metrics and compensation
- ✔ lightning detection and isolating the campus when a threat is present
- ✔ comparing overall power levels (real and reactive) with desired levels and taking action to sustain the desired levels
- ✔ the ability to detect voltage disturbances on the utility system and make a quick decision (within a few cycles) as to whether or not to stay connected or separate as an island
- ✔ the ability to discriminate between disturbances originating on the utility system versus those originating on the microgrid in order to initiate appropriate switching and protection steps
- ✔ the ability to sense and isolate faults while rerouting power to ensure power supply to all loads.

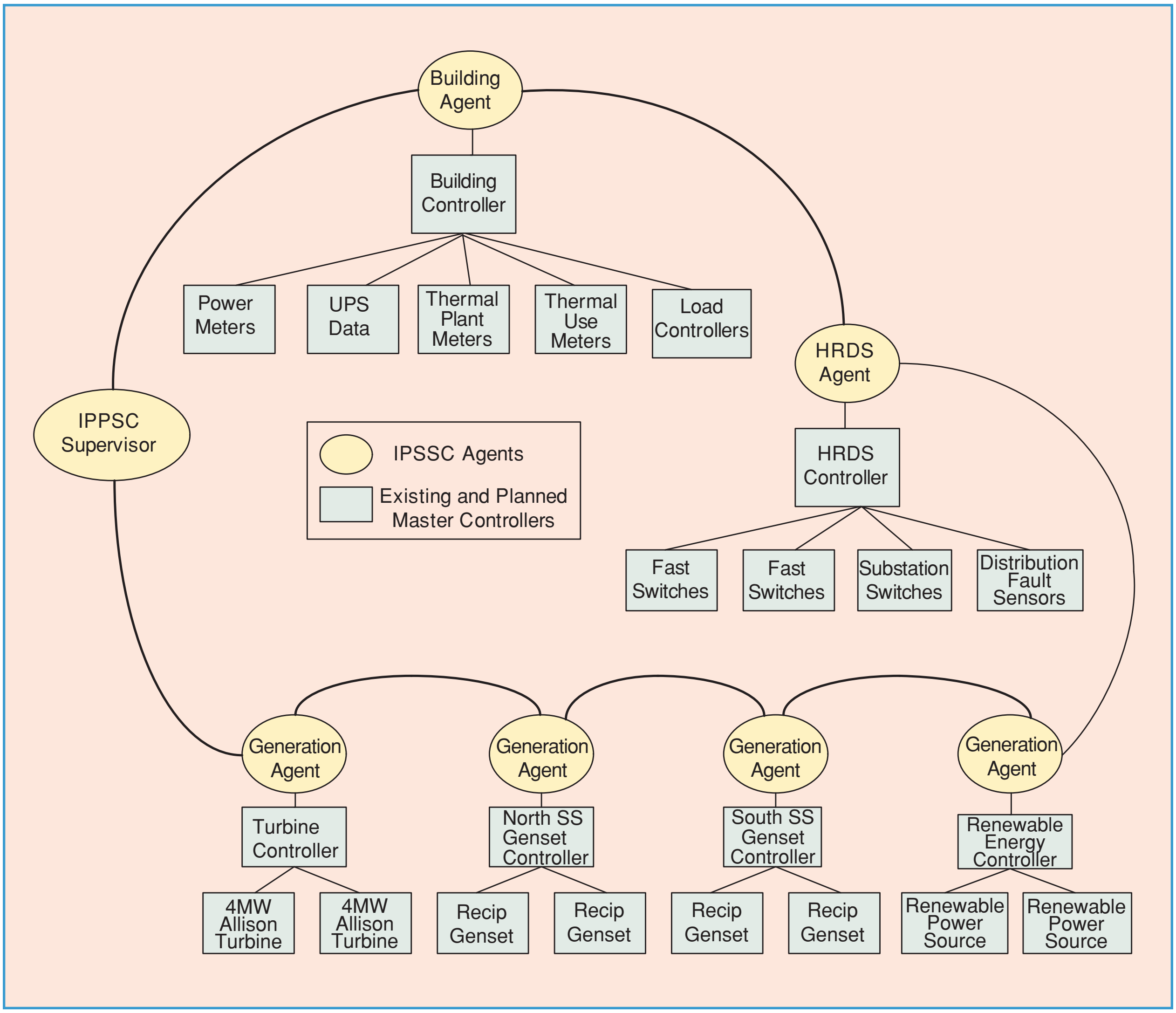


figure 8. IPPSC agent concept.

The increased reliability, demand response capability, and the on-site generation will provide the desired redundance, while avoiding the cost of a new substation.

Response to Price Signals

The IIT campus is located within the PJM ISO territory. 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 4-MW turbines and the proposed MW of substation sited generation to provide ancillary services to the PJM ISO. Specifically, IIT can participate in the following markets:

- ✔ **Real-time pricing**. The PJM ISO allows for purchase of electricity in real time. Most facilities do not engage in real-time markets due to price volatility risks. However, the perfect power system provides IIT with the ability to generate electricity for the entire campus at a fixed price, thereby providing a hedge when real-time prices exceed 7–8 cents per kWh. This will allow IIT to purchase electricity from the lower cost real-time markets and deploy its backup generation when the price of electricity exceeded 7–8 cents/kWh (backup generation marginal cost). This would result in approximately US$1 million in savings based on the current Constellation contract electricity costs and 2005/2006 PJM real-time prices.
- ✔ **Spinning reserve**. 2006 was the first year that demand reduction was allowed to participate in the spinning reserve market. This requires reduction of load within ten minutes of receiving a request from the PJM ISO. The value of this market is minimal.
- ✔ **Day ahead economic load response**. IIT can bid a price in the day-ahead market specifying the times and duration that the demand reduction is available. The PJM ISO will call on IIT the day before with a request for kilowatts and a time slot.

To support real-time markets, IIT would need to upgrade the two 4-MW natural-gas-fired turbines that are currently configured to provide prime power and steam to the campus. This will provide a local redundant power source and position IIT to purchase lower cost real-time electricity.

Conclusion

The objectives of the perfect power project include: 1) the achievement of system-wide perfect power and demonstration of its technological viability; 2) 50% peak demand reduction capability via on-site generation when called upon by ComEd/PJM; 3) deferral of ComEd planned substation upgrades due to the demand reduction achieved; 4) 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; and 5) a design that can be replicated to any municipality-sized system where customers can participate in electric power market opportunities.

In addition, the IIT team seeks to fulfill the mission of the university as set forth by President John L. Anderson, "IIT will be internationally recognized in distinctive areas of education and research, using as its platform the global city of Chicago, driven by a focus on professional and technology-oriented education, and based on a culture of innovation that embraces bold and transformational ideas."

Transforming the IIT power delivery infrastructure to achieve perfect power is a bold idea that will require a never-ending series of innovations. We have embraced the vision of the GEI and we look forward to sharing our progress with the power and energy community in the years to come.

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For Further Reading

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