Smart Grid: A New Paradigm for Power Delivery

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Topics

- Elements of Smart Grid
- Implementation of DOE Smart Grid Project at IIT
- Conclusions

Electric Grid is a Complex System with Unique Characteristics

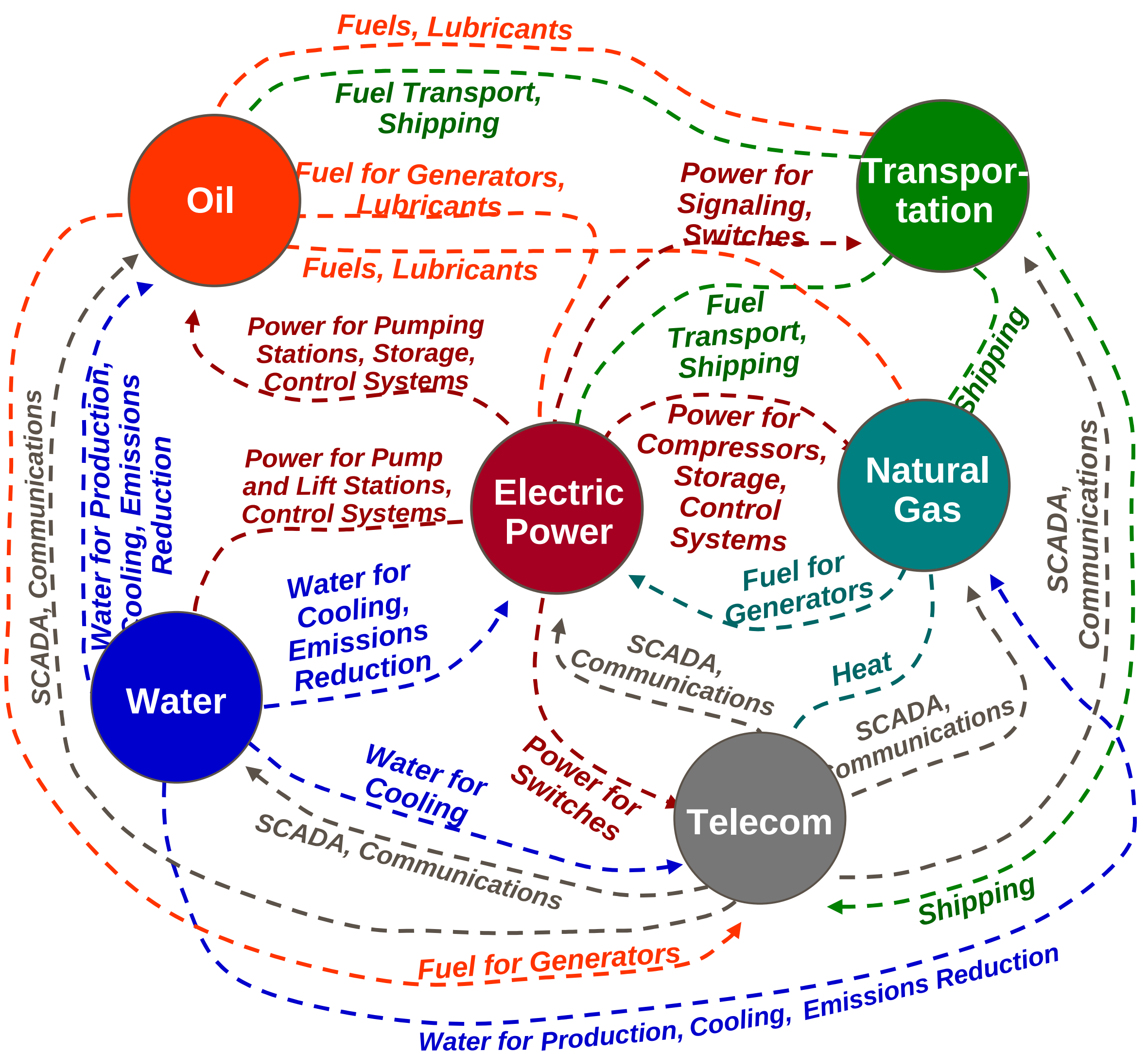
Physically

- Not holistically designed, evolved incrementally in response to local load growth.
  - 30,000 Transmission paths; over 160,000 miles of transmission line
  - 14,000 Transmission substations
  - Distribution grid connects these substations with over 100 million loads
- Diverse industry without a common voice
  - 3,170 traditional electric utilities
  - 239 investor-owned, 2,009 publicly owned, 912 consumer-owned rural cooperatives, and 10 Federal electric utilities

Technically

- Electricity flows along paths with lowest impedance; yet the grid is operated in a decentralized manner by over 140 control areas
- Demand is uncontrolled; electricity production is the ultimate “just-in-time” process

Interdependent Infrastructures



Innovations in Electricity Infrastructure

- **Supply Adequacy and Economics:** Applications of renewable energy, storage technologies for enhancing the security, coordination of renewable and storage supplies, carbon footprints
- **Transmission Expansion and Security:** Expansion planning of transmission facilities, coordination of energy infrastructures, superconductors, HVDC, physical and cyber security, wide area measurements, PMUs
- **Smart Grid:** Energy efficiency, price response, peak load reduction, distribution automation, new building technologies, smart metering, sensors, communication and control techniques

What is a Smart Grid?

- Smart grid is a response to economic, security, and environmental mandates placed on energy supply and delivery
- Smart grid provides access points that can be identified, much like computer devices, with an IP address on the internet
- Smart grid uses the internet protocol to shuttle information back and forth between the utility and customers
- With two-way communications between consumers and suppliers, both parties can get far more control over the grid consumption, and physical and cyber security

Consumer's Dilemma

- Today, most consumers know little about costs that show up on their electricity bills except that they are higher during hot and cold months
- Few consumers realize that the true price of electricity varies continuously in response to supply and demand, and that electricity bills are mostly calculated based on average prices
- Since consumers do not adjust energy use in response to high prices, they are likely to use electricity at peak hours more than what they need to — and thus pay more than what they would have to

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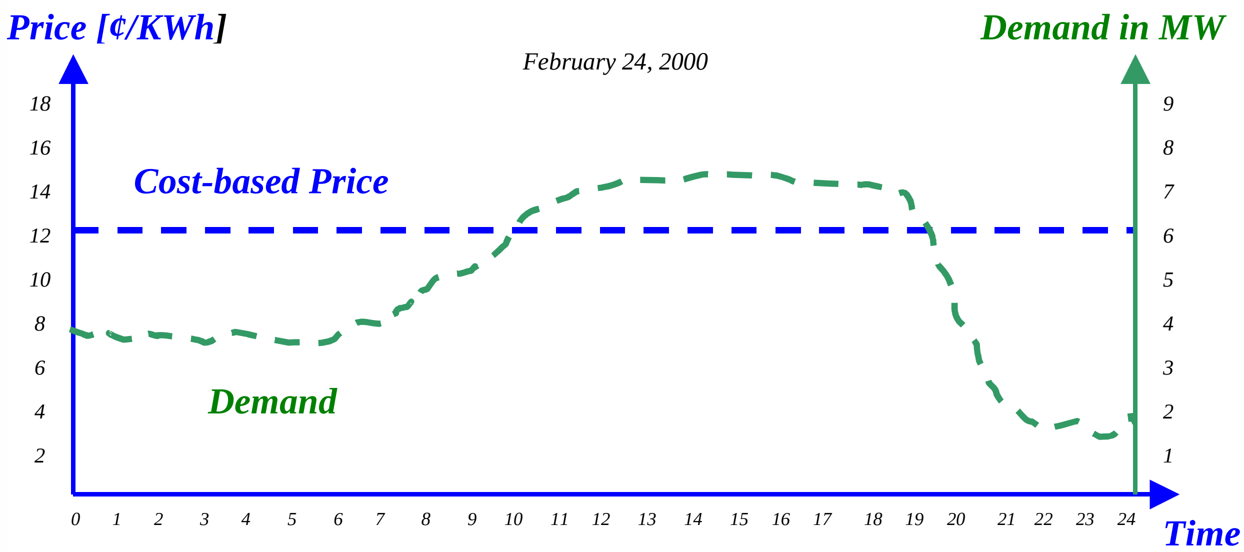
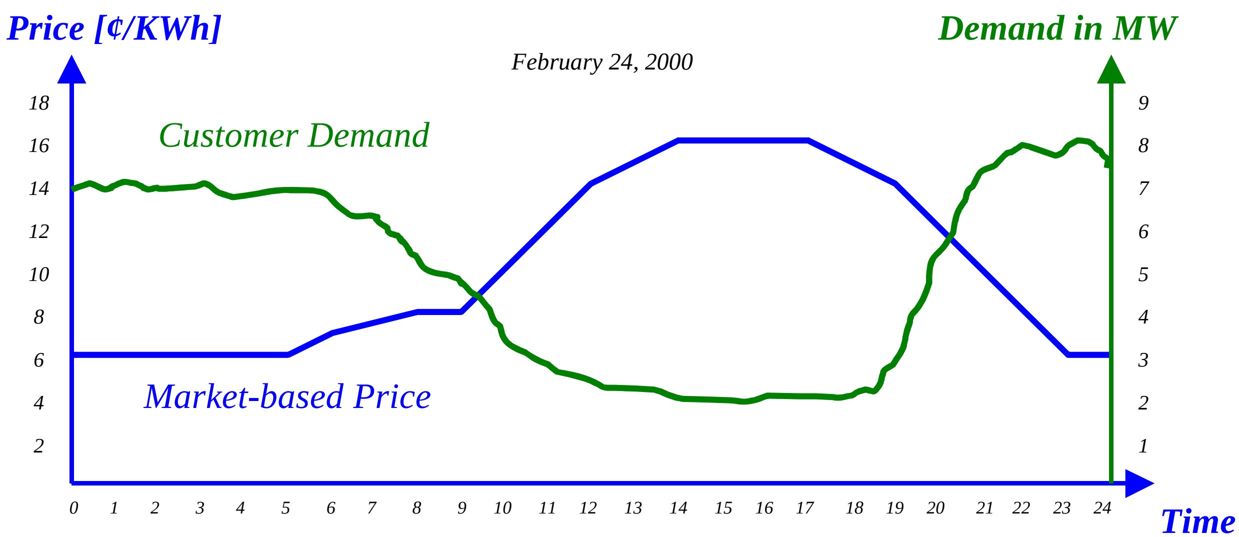


Behavior of a Demand in a Vertically integrated Power Market

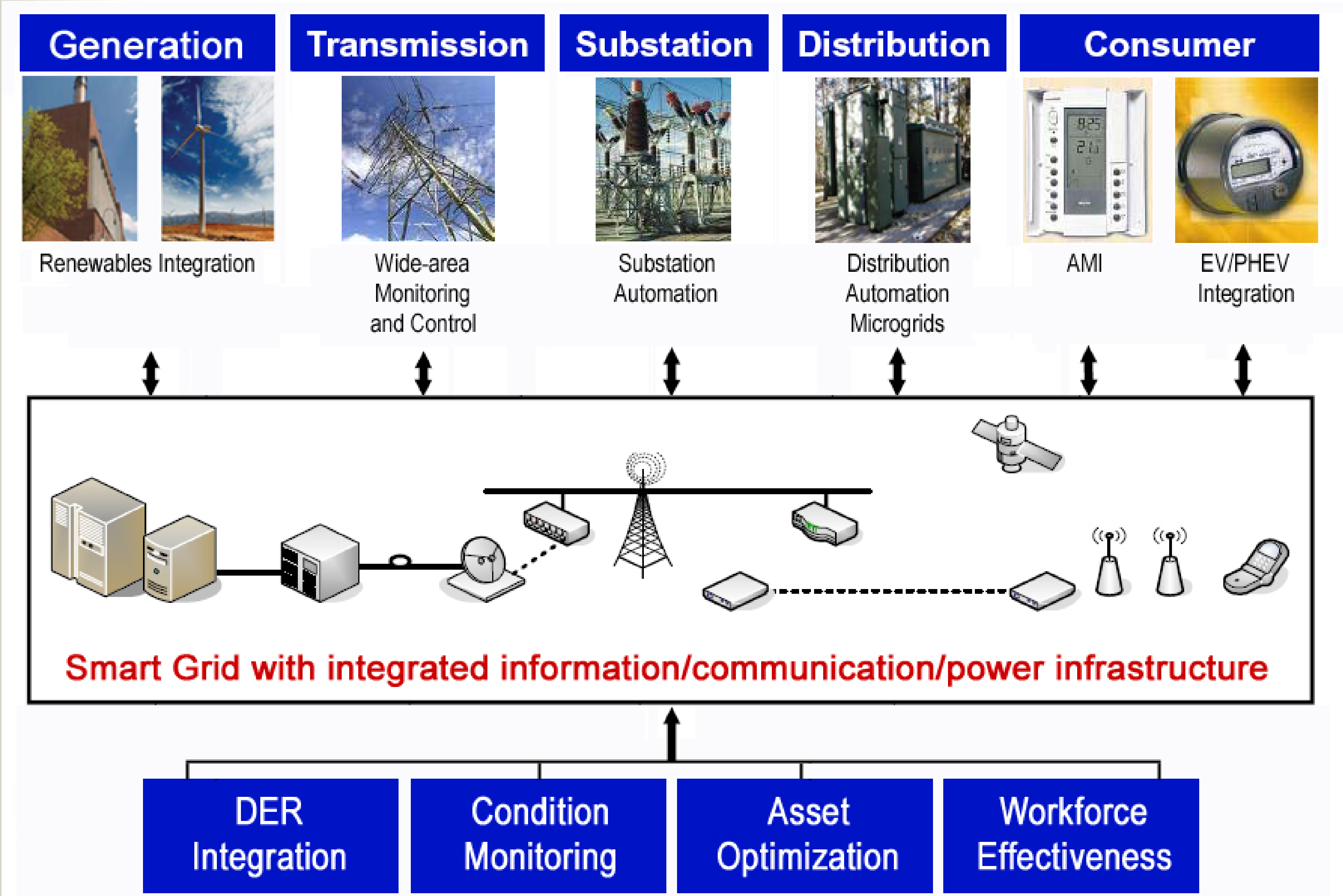


Response of a Demand to Price Signals

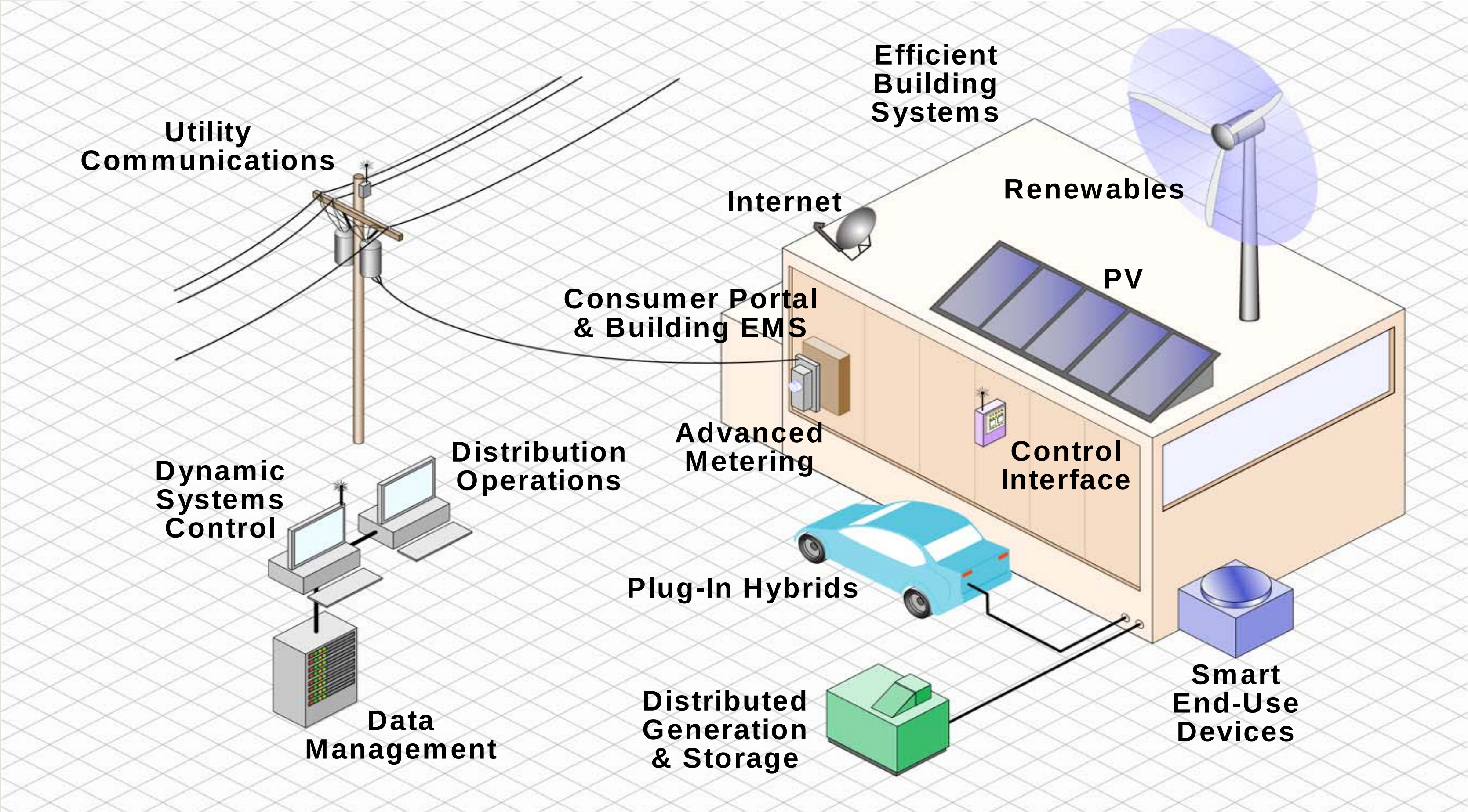
Elements of Smart Grid

- Distribution automation
  - Self-healing distribution systems
    - Rapidly detect, respond, restore, and communicate
- Self-sustaining on-site generation with storage
  - Provides alternative supply of energy
- Leveraging lower carbon generation sources
  - Solar PV, natural gas, wind, hydro, geothermal, biofuel,
- Demand response / empower consumers
  - Smart meters
  - Real-time pricing of electricity

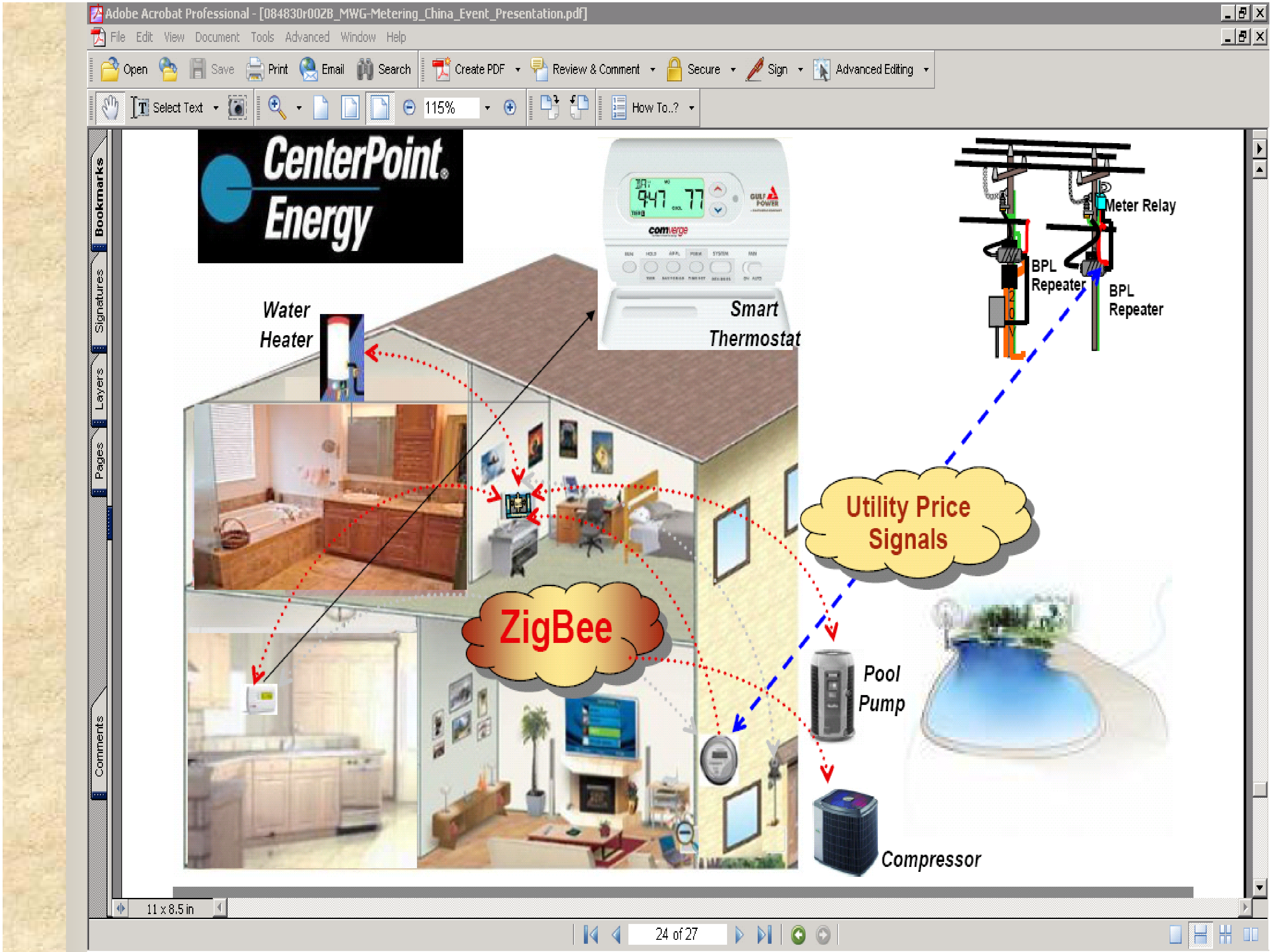
Power Systems and Smart Grid



Smart Grid - *Consumer Opportunities*



Energy efficiency and demand response is a driver that will greatly accelerate the creation of a smart grid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BPL Repeater
Utility Price Signals
ZigBee
Pool Pump
Compressor
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Advanced Metering Infrastructure (AMI)

- AMI combines three core components
  - Smart sensors at customer premises,
  - Two-way communications,
  - Master controller for managing and metering hourly energy use
- Smart sensors installed at consumer premises measure, monitor, and help manage energy use
- Two-way communication links include cellular networks, satellite, and radio frequency networks
  - AMI revolutionizes electric outage detection and restoration by providing utilities with customer outage information
- Master controller uses the hourly price information to provide consumers with real time data to ensure a seamless consumer experience.

Business of Smart Grid

- Smart grid technologies would reduce power disturbance costs to the U.S. economy by $49 billion per year
- Smart grid would reduce the need for massive infrastructure investments by $100 billion over the next 20 years
- Deployment of smart grid allows consumers to easily control and lower their power consumption
    - It could add $5 - $7 billion per year back into the U.S. economy by 2015 and $15 - $20 billion per year by 2020

Perfect Power at Illinois Institute of Technology

- Funded by the U.S. Department of Energy
- $12M ($7M from DOE, $5M Cost Share)
- 5 year project
- Located at Illinois Institute of Technology (IIT)
- Involves the entire campus
- Partners: IIT, Exelon, S&C, Schweitzer, Endurant

Vision for Perfect Power

“The perfect power system will ensure absolute and universal availability of energy in the quantity and quality necessary to meet every consumer’s needs. It is a system that never fails the consumer.”

Bob Galvin

Elements of Perfect Power

- Distribution automation
- On-site generation: gas unit, back-up power
- Leveraging lower carbon generation: renewables
- Demand response / empowering the campus

DOE/IIT Project Goals

- 50% peak demand reduction
- 20% permanent demand reduction
- Demonstrate the value of Perfect Power
  - Cost avoidance and savings in outage costs
  - Deferral of planned substations
- New products and commercialization
- Replicable to larger cities
- Promotion of energy efficiency and cleaner cities

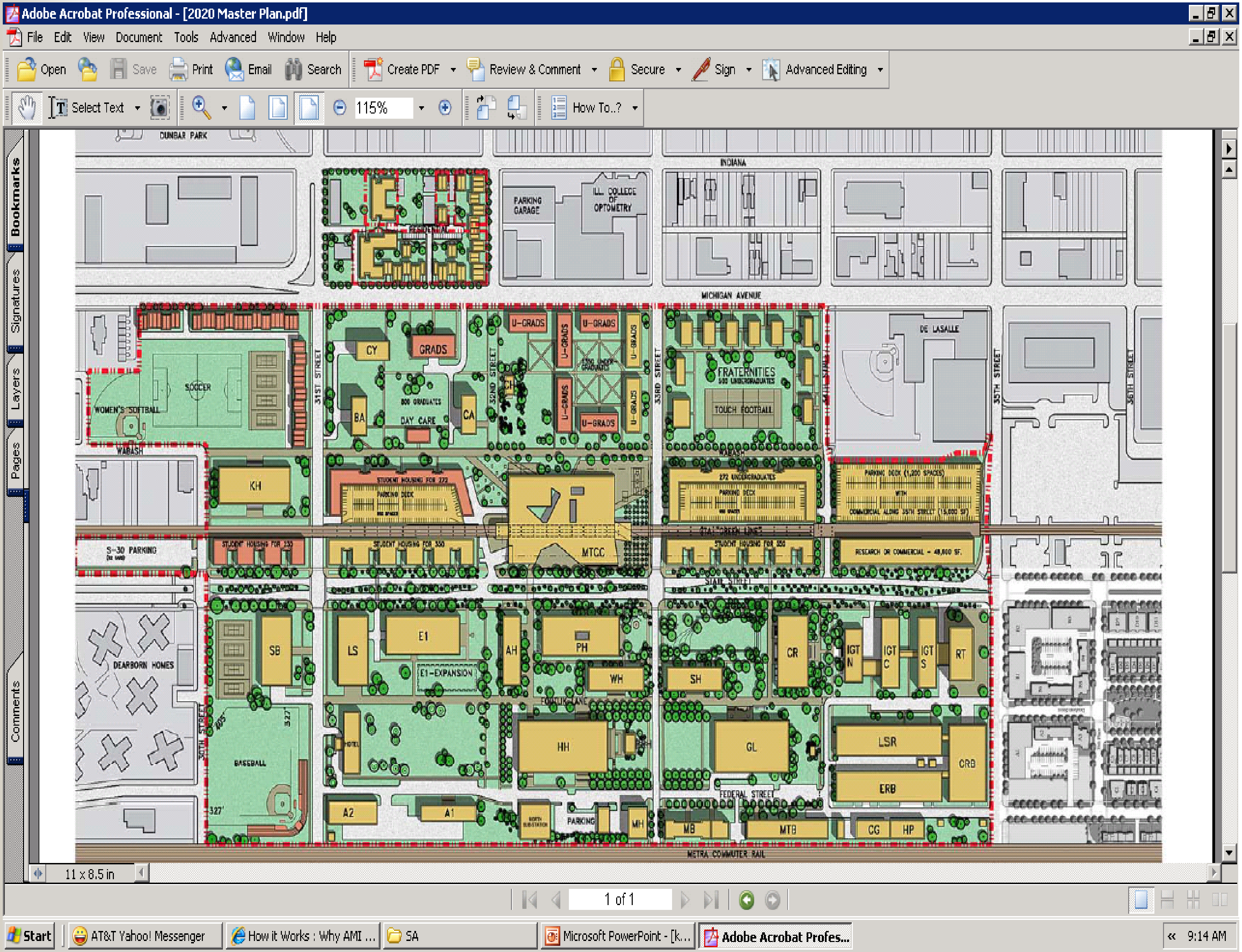
Why would IIT Need Perfect Power?

- At least three power outages per year
  - Costs = up to $500,000 annually in restoration costs, lost productivity and ruined experiments
- Electricity costs were doubled within the last decade
- Addition of two new resident halls require more power
- Campus electricity infrastructure would need to be upgraded
- Electricity demand is growing with increased student population
- Installation of additional building equipment adds to energy use
- Renegotiating electricity contract will allow real-time pricing

Savings Outweigh the Lifecycle Costs

PERFECT POWER COSTS	
BENEFIT	**COST**
Redundant cabling	$1.5M
Intelligent switches and meters	$5M
Solar PV, UPS, storage	$600,000
On-site generation	$1M
Communications and controls	$1.4M
Substation recommissioning and automation	$2.5M
TOTAL SYSTEM COSTS	**$12M**

IIT SAVINGS/COST AVOIDANCE		
BENEFIT	**PERIOD**	**SAVINGS**
Avoided IIT distribution upgrades	One time	$5M
TOTAL ONE-TIME SAVINGS		**$5M**
Electricity cost reduction • Real-time pricing	Annual	$600,000
Demand response	Annual	$400,000
Outage costs	Annual	$300,000
Capacity payments	Annual	Later
TOTAL ANNUAL SAVINGS		**$1.3M**
Simple payback period		5 years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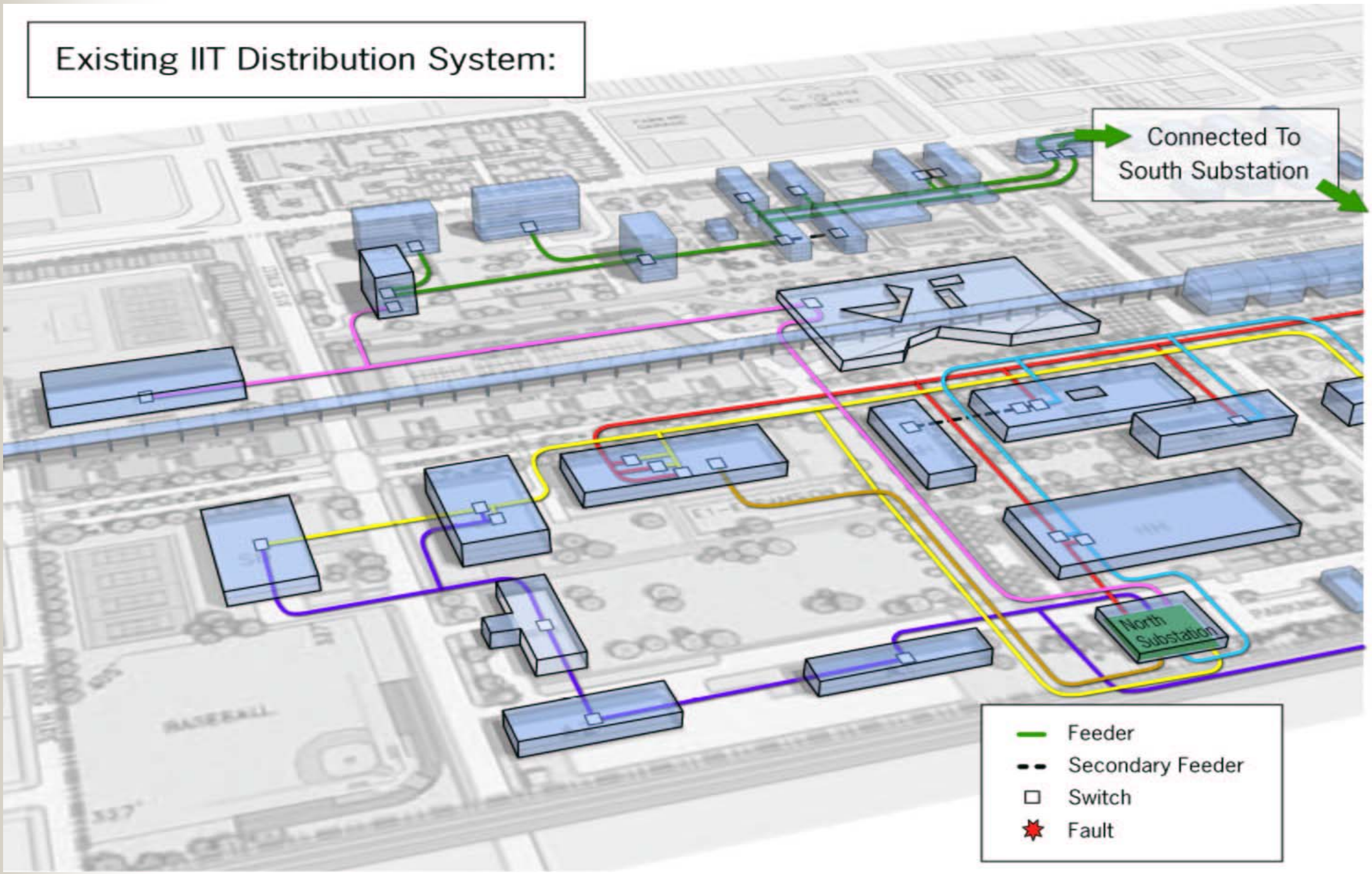
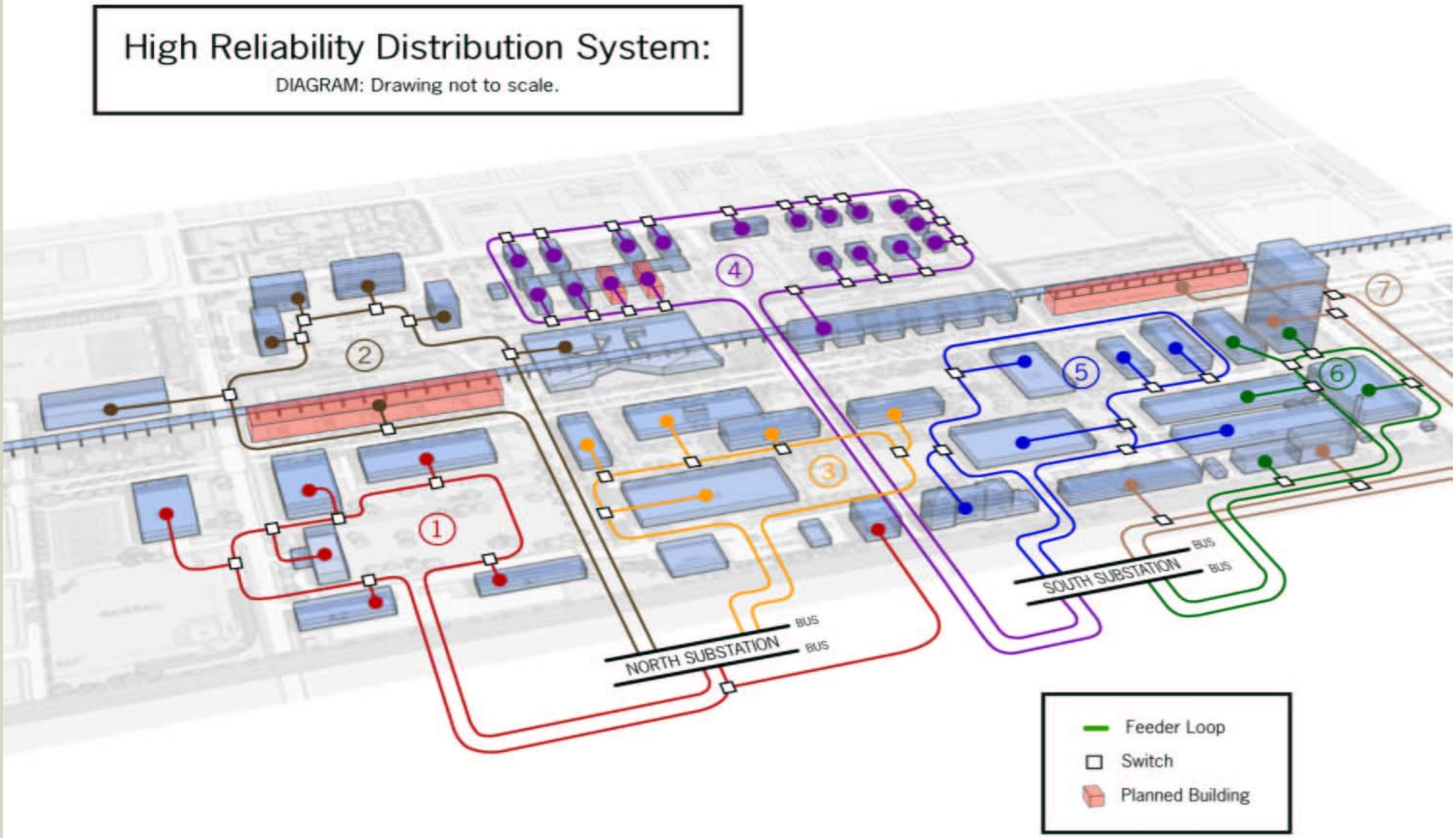
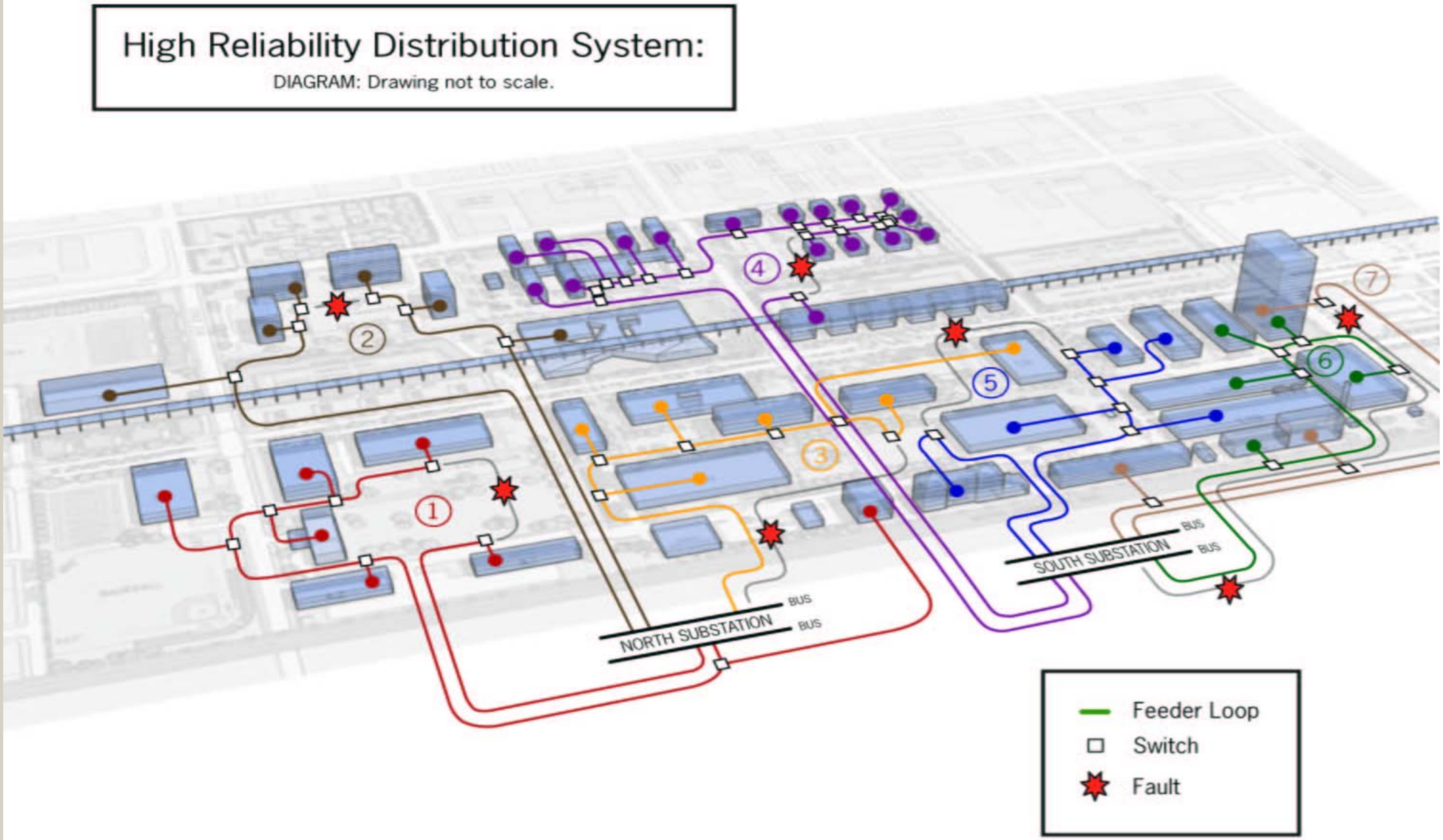
IIT Before Perfect Power

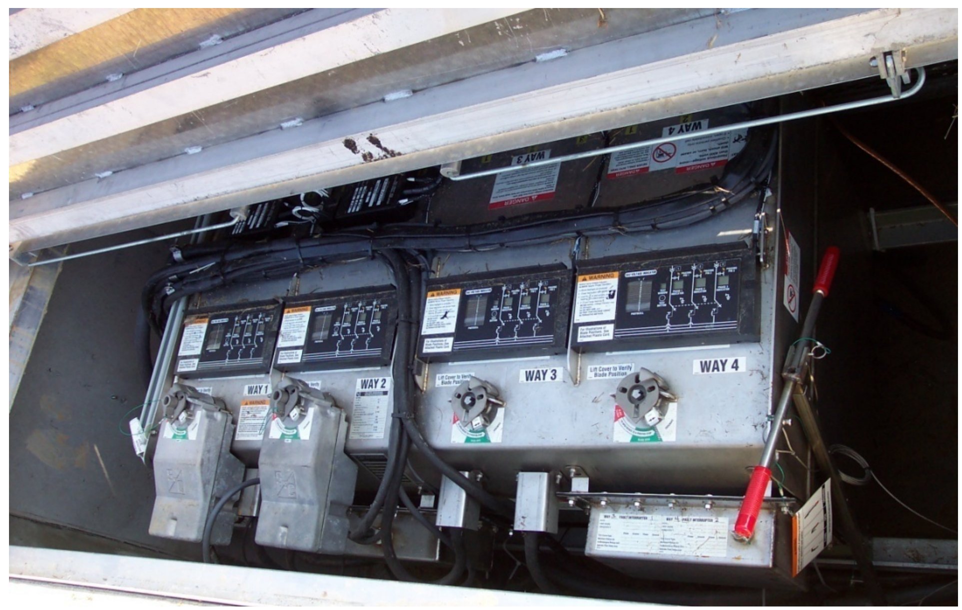


IIT with Perfect Power



Even with Faults, Perfect Power Stays On

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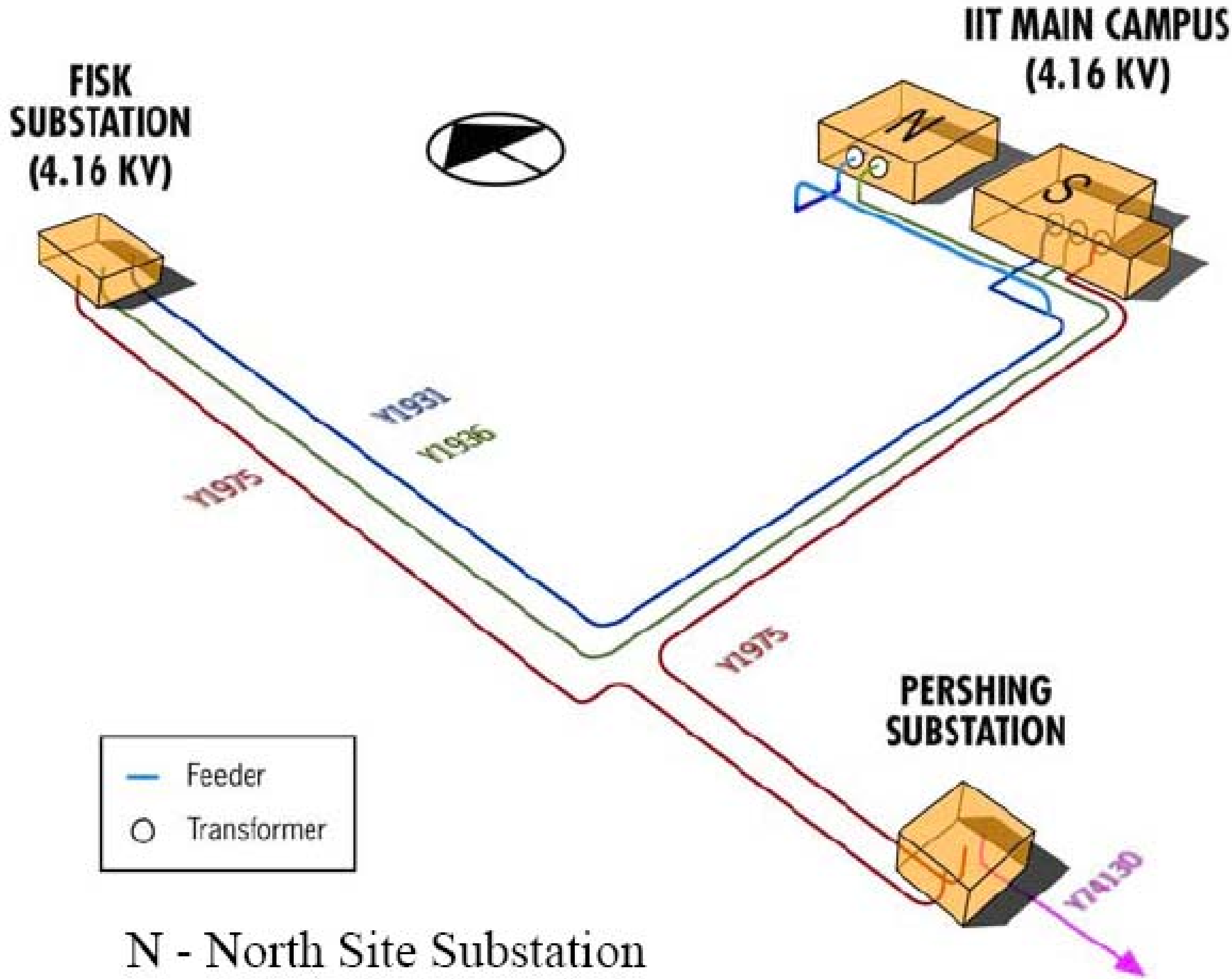
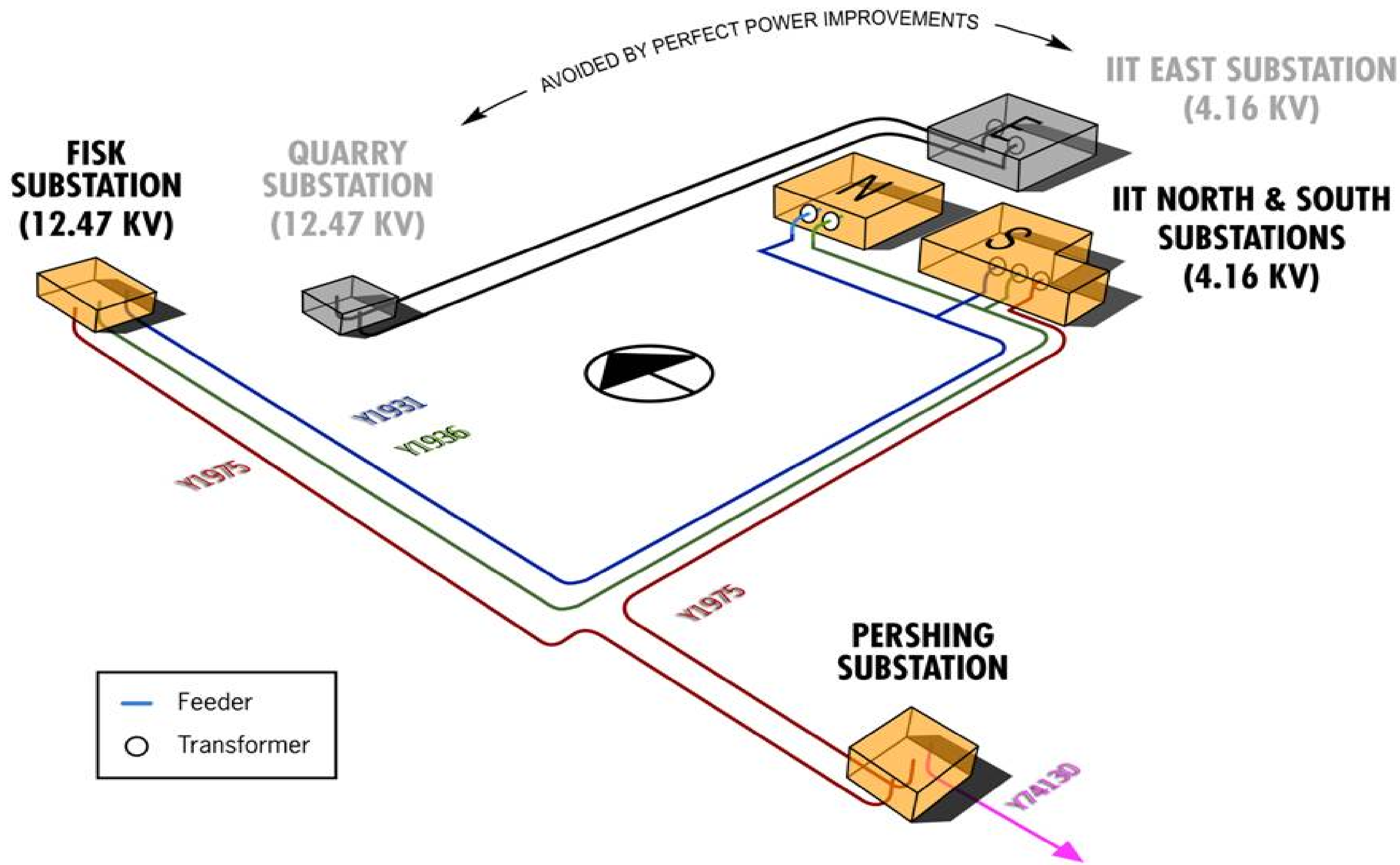


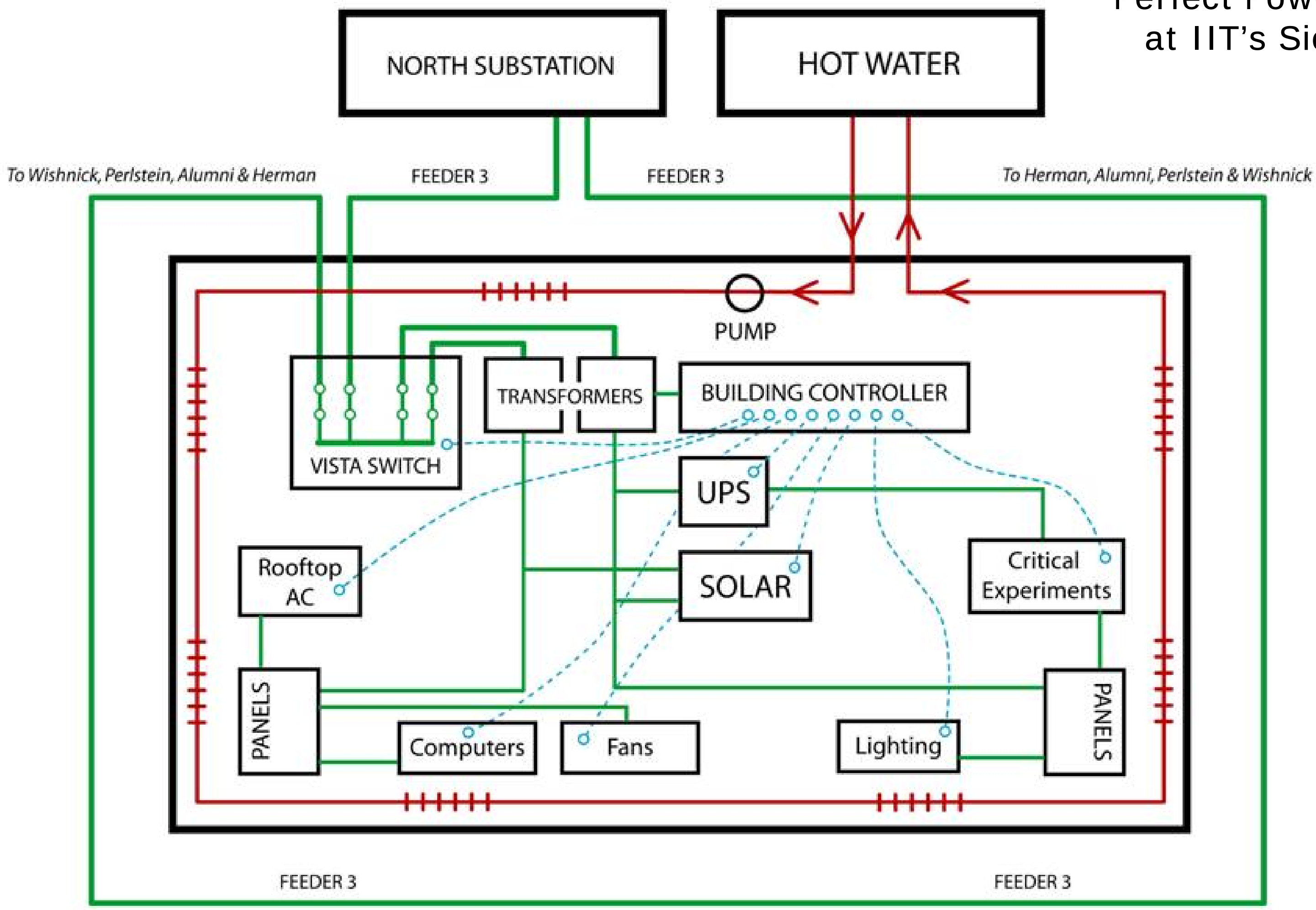
N - North Site Substation
S – South site Substation

No Additional Substations—Perfect Power



Look of Perfect Power at IIT

Perfect Power System
at IIT's Siegel Hall

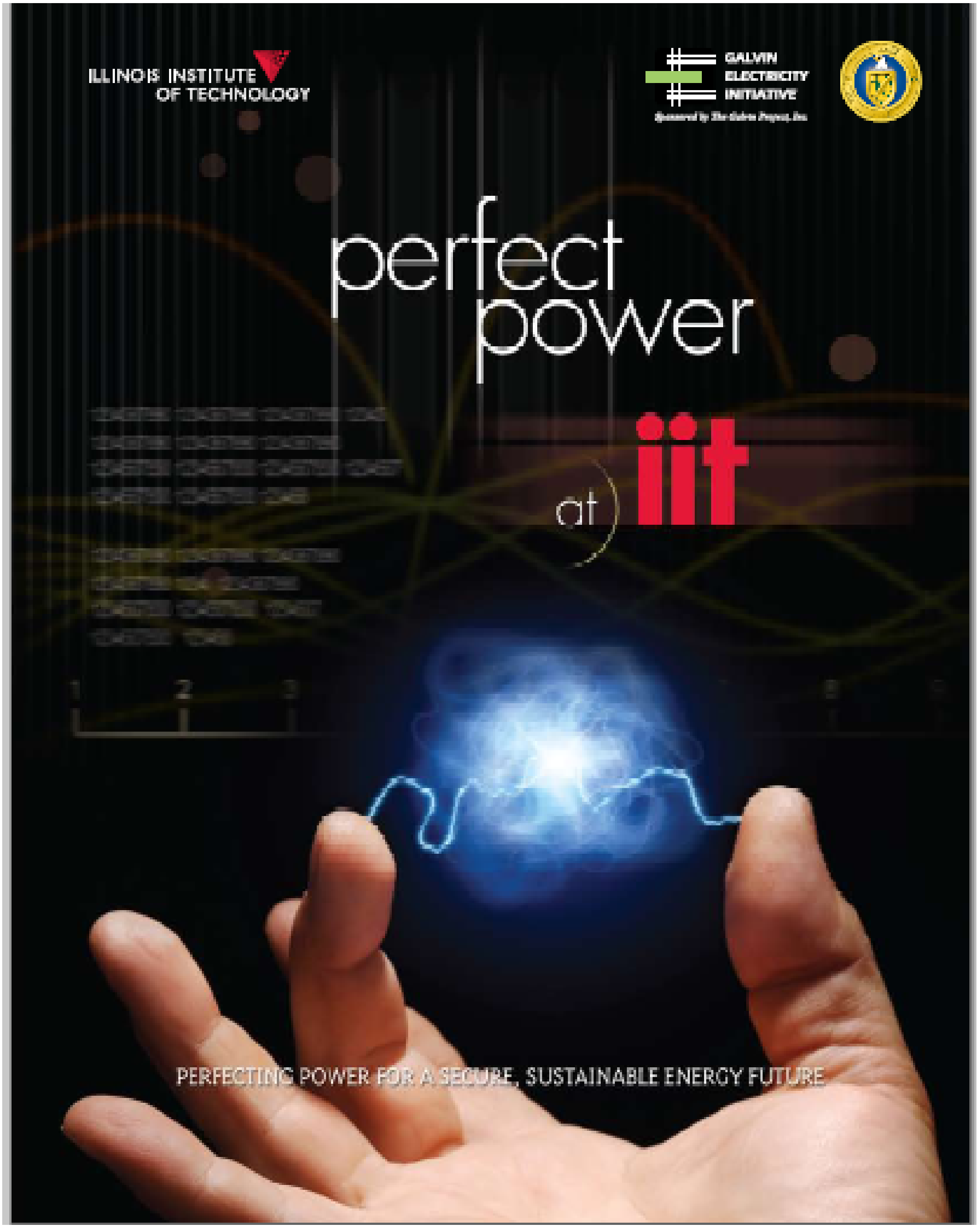


Perfect Power Benefits to IIT

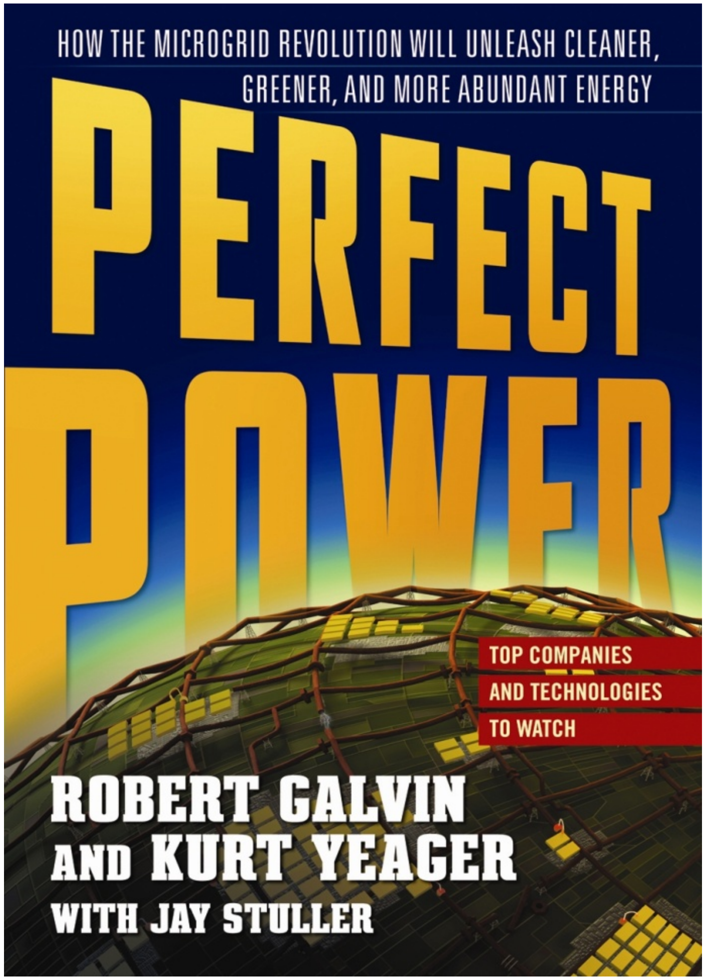
- Reduced energy costs
- Improved power reliability and quality
- Reduced need for scheduled upgrades
- Reduce IIT's carbon footprint
- Cost and infrastructure benefits for ComEd
- Expanded education and research
- Improved campus safety and security

DOE's Perfect Power Research Scope

- Distribution Automation Recovery
- Intelligent Perfect Power Controller
- Advanced Zigbee Technology
- Buried Cable Fault Detection



ILLINOIS INSTITUTE OF TECHNOLOGY
GALVIN ELECTRICITY INITIATIVE
perfect power
at iit
PERFECTING POWER FOR A SECURE, SUSTAINABLE ENERGY FUTURE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