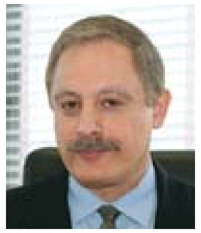
energy@iit

Department of Electrical and Computer Engineering
Electric Power and Power Electronics Program

ILLINOIS INSTITUTE OF TECHNOLOGY



It is my pleasure to present the energy@iit magazine from the Department of Electrical and Computer Engineering at Illinois Institute of Technology. It symbolizes our evolution as a leading institution in engineering research and the importance of education in creating a sustainable world. We are working to perfect power generation, distribution, and use through three key areas of technology: smart grid design and implementation, energy efficient machines and systems, and renewable energy production and utilization.

This is a very exciting time for us. We are embarking on many projects including the creation of a Perfect Power Prototype with DOE and the Galvin Electricity Initiative to demonstrate and promote energy efficiency and sustainability at the national level. By dedicating our campus, faculty, and students to perfecting power we have become a living laboratory to promote change in all facets of energy research.

I hope you enjoy reading about our progress in creating a more energy efficient and sustainable world. Thank you for your continuing support.

Mohammad Shahidehpour
Carl Bodine Professor and Chair
Department of Electrical and Computer Engineering

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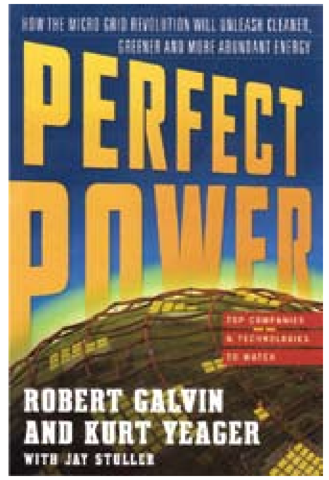
Director of Communication: Amy Henson

Electrical Engineering and Power Degrees

Doctor of Philosophy in Electrical Engineering
Master of Science in Electrical Engineering
Master of Power Engineering
Master of Electricity Markets
Master of Electrical and Computer Engineering
Bachelor of Electrical Engineering
Bachelor of Electrical and Computer Engineering

The Department of Electrical and Computer Engineering at Illinois Institute of Technology is working with the Electric Power Research Institute, Exelon, Endurant, and S&C Electric, as well as industry leaders Robert Galvin and Kurt Yeager to implement Perfect Power at IIT. See Galvin and Yeager's book *Perfect Power* for more information on the project.



Department of Energy and Illinois Institute of Technology Bring Perfect Power to Chicago

The Department of Energy (DOE) has awarded a five-year $7 million grant to be paired with Illinois Institute of Technology's investment, totaling $12 million to bring Perfect Power to IIT Main Campus in Chicago. Department of Electrical and Computer Engineering Chair Mohammad Shahidehpour is principal investigator for the project. Perfect Power—the first such system to be built in the United States—will be a university-owned, campus-wide smart microgrid electricity distribution system that will virtually eliminate power outages by providing more reliable, efficient, and secure electricity to IIT's classrooms and research facilities. See page 2 for more on Perfect Power.

Recent gifts and grants include:

The Grainger Foundation donated $5 million to promote power engineering education and research at IIT. The endowed gift supports about 15 students per year for continuing their studies in power engineering.

A $650,000 grant from DRS Test and Energy Management, Inc. for a multidisciplinary research project on converting military vehicles to hybrid.

Five-year, multi-million dollar grant from the Department of Energy to establish a Perfect Power system model at IIT.

Paul McCoy (EE '72) gave an endowed gift of $500,000 to initiate a power engineering scholarship in the ECE department.

A $300,000 grant from the National Science Foundation for studying power system outages in the United States.

A $100,000 grant from the Korea Power Exchange for the design of the next generation of an energy management system in Korea.

A $340,000 grant from the National Science Foundation for developing renewable hydro-wind energy units.

A $350,000 grant from the National Science Foundation for developing chargers and converters for plug-in hybrid electric vehicles.

Lighting the Way to Perfect Power

Each year major cities throughout the world are inevitably stuck during power outages, waiting for their world to light up again.

This is evidence of a global energy crisis that is no longer in the distant future; it's on our heels. Illinois Institute of Technology has partnered with the Galvin Electricity Initiative to convert IIT Main Campus into the flagship Perfect Power system in the United States, which will confront and model a solution to the global energy crisis. The Department of Energy (DOE) has also joined the effort, providing a $7 million grant to be paired with IIT's $5 million investment in the project. ECE Department Chair Mohammad Shahidehpour, Professors Alex Flueck, Zuyi Li, and Chi Zhou, and more than 60 independent experts are aiding the initiative in building the system at IIT.

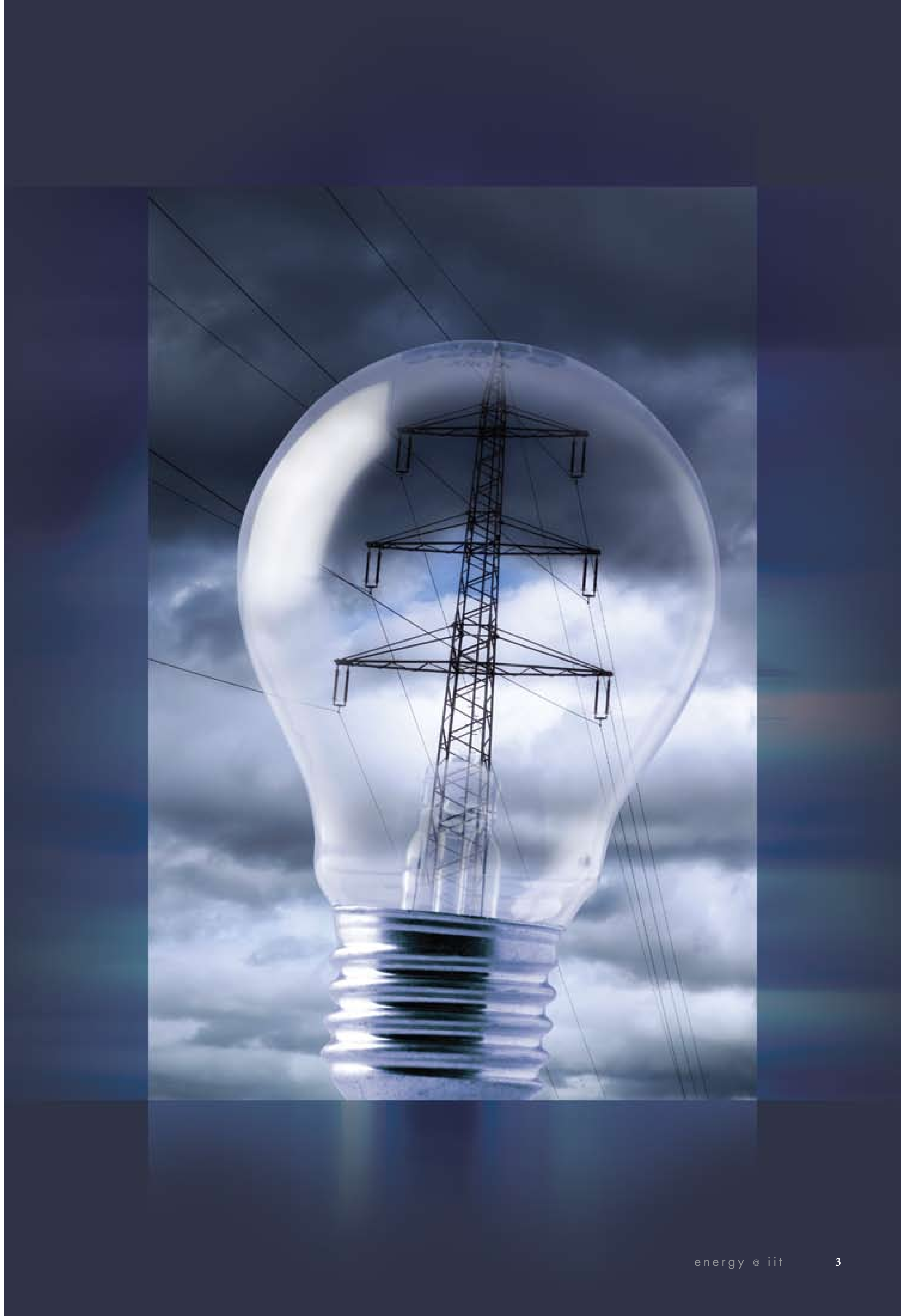
The team will implement local microgrids to act as intelligent, consumer driven capillaries fed from the existing electricity distribution arteries. Using this approach, the system can adapt to trends in electricity usage and change the supply accordingly, producing less waste. The system consists of smart infrastructure featuring a loop system and redundant electricity network. It will offer IIT the opportunity to make necessary system upgrades—eliminating costly outages, minimizing power disturbances, moderating an ever-growing demand, and curbing greenhouse gas emissions.

IIT's Perfect Power system will include the following elements:

- Smart grid and technology-ready infrastructure
- Self-sustaining electricity infrastructure
- An intelligent distribution system and system controllers
- Onsite electricity production
- Demand-response capability
- Sustainable energy systems and green buildings/complexes

Over the course of the last hundred years, electricity has increased humankind's ecological footprint on the planet 100 fold. "While electricity has produced tremendous good over the past century, it has also created side effects, which must be resolved if we are to achieve a sustainable world," says Kurt Yeager, executive director of the Galvin Electricity Initiative.

The initiative and IIT are beginning to build with the ultimate goal of sustainability and creating a long-term solution for powering the IIT community. To do so, they are integrating the perfect power system into the current infrastructure. The intelligent system will fundamentally increase efficiency, reducing the need for fossil fuels and the resulting CO_2 emissions.



Perfect Power Components

Distribution Automation and Recovery System

Professor Alexander Flueck, in collaboration with S&C Electric Company, will lead research to develop and demonstrate advanced monitoring for distribution automation. The team will create a system for sensing distribution system conditions and automatically reconfiguring the system to respond to disturbances. The proposed program will accelerate deployment of new technologies for agent-based distribution automation, including fault detection, location, and isolation, feeder reconfiguration, volt/VAR management, service restoration, emergency response, and integration of distributed resources. The technologies will be deployed in the Perfect Power system at IIT.

Renewable Energy

Integration of renewable energy is a cornerstone of the Perfect Power Prototype at Illinois Institute of Technology. By purchasing energy from local renewable resources, the system will use dispersed generation to improve reliability and cost-effectiveness. Local renewables include power from area wind farms and hydroelectric power from dams such as the Fox River Dam in Aurora, Ill. Research and education on hydroelectric technology has grown immensely at IIT with support from ECE alumnus Alex Tseng (IE ’49, M.S. EE ’50). Among his many projects with the university, Tseng recently worked with Professor Zuyi Li to design the hydroelectric waterfall prototype to be installed in Siegel Hall.

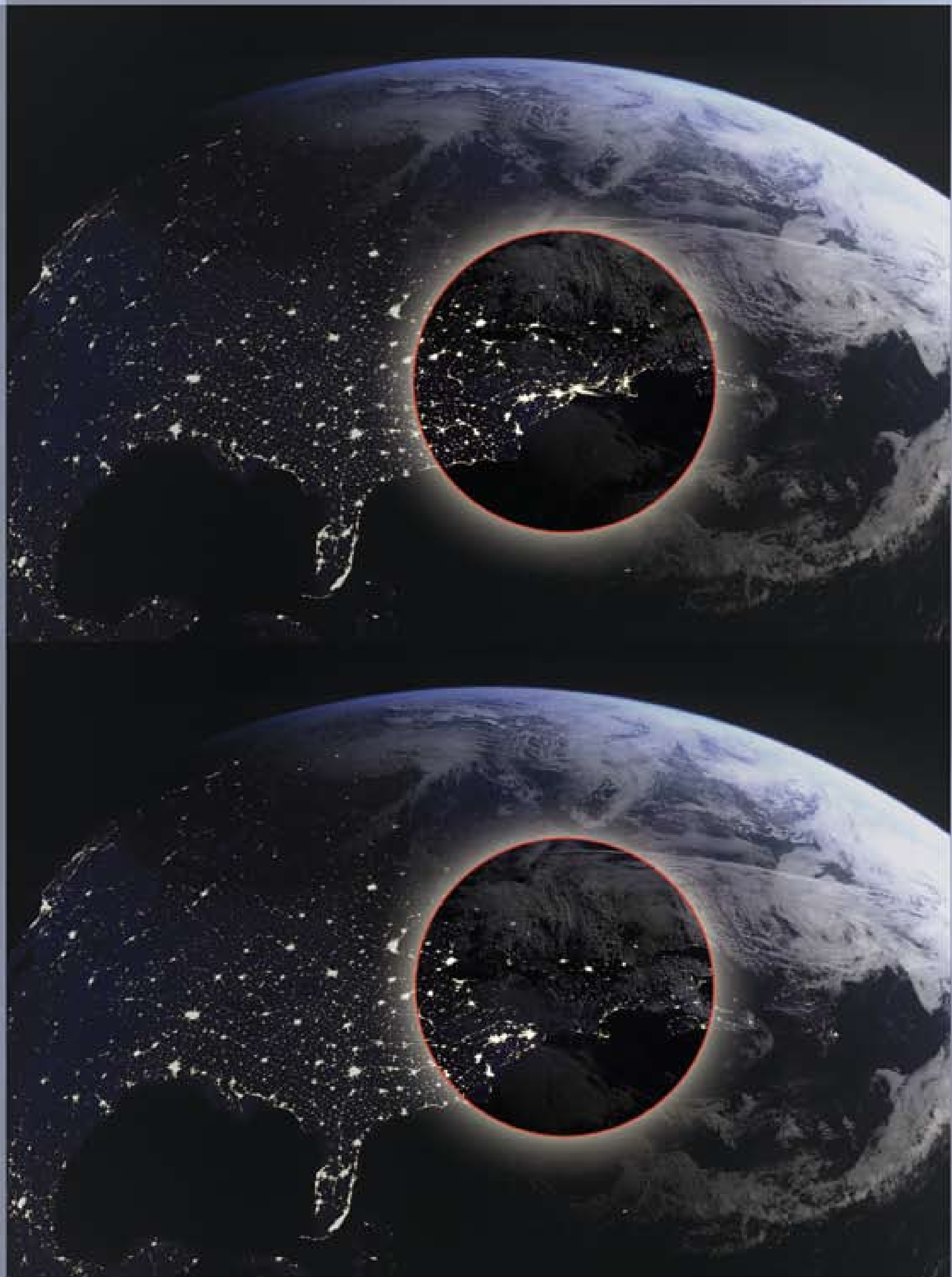
Smart Metering for Greener Homes

Creating truly green homes and businesses requires consumers to be able to actively participate in their energy use; smart meters and smart grids make it possible.

Electricity prices peak at certain times of the day and season based on demand. When temperatures rise, for example, there is high electricity demand to power air conditioners. Prices rise significantly because power companies must buy from more expensive sources of power to make up for the heavy use. Smart meters are a way for every consumer to customize their energy bill by buying electricity based on current prices. A consumer can save money annually if they are willing to adjust their consumption habits to be more responsive to market prices of electricity.

This system is beneficial for industry and homeowners alike, especially if it is used as part of a smart grid. Smart grids use two-way communication with smart meters to distribute power using up-to-the-minute pricing. They also allow more flexibility in what kind of energy is purchased and when, which allows consumers to automatically generate their own electricity via renewable sources such as solar panels when prices are high, thus reducing their electricity bill and contributing to global energy conservation.

The Perfect Power Prototype being constructed at IIT Main Campus will use ZigBee wireless with smart meters to demonstrate how implementing smart grids and meters can help consumers on a national level. The IIT communications network, researched and developed by Professor Chi Zhou and Visiting Professor Lei Wu, will control and reduce loads and manage energy-saving programs on campus. ZigBee will also allow the system controller to monitor, collect, and analyze data on energy usage at IIT for managing system disturbances while sending wireless signals to control lighting, office and laboratory usage, HVAC, water heaters, and distributed generation.



This global illustration shows potential effects of poor outage planning and security during a northeast United States blackout.

Planned Power Outages:
Managing Security While Repairing the Grid

The lack of efficient outage management in electric power systems is one of the most important factors in a rapidly aging electricity infrastructure.

The restructuring of the electricity industry in the 1990s included unbundling generation and transmission assets. In the restructuring, generating companies and transmission companies are represented as independent agents who are responsible for managing their own planned outages. A major concern is that these companies could base their outage management objectives more on maximizing profits than ensuring security and smooth system operation. Logically, energy companies would plan equipment outages when electricity prices are low, reducing the amount of revenue lost, but also opening new doors to security threats. This lack of coordination could also complicate the job of Independent System Operators who manage the security of power grids.

According to the Energy Information Administration, 60 percent of generators in the United States are more than 20 years old, and 50 percent of those were built 30 years ago. Alarmingly, the average life of an electricity market transformer is only 36 years. This means that power companies must schedule maintenance or replacement of a number of generating units and transmission lines in a competitive market while maintaining the power system security. To do this effectively, independent operators must manage when and how to shut off the units and run power via alternate routes, which is an excessively detailed procedure in a congested transmission grid.

Professor Zuyi Li and Visiting Professor Yong Fu are working on this issue by developing optimization algorithms for Siemens Corporation to manage power system planned outages in Russia. The proposed algorithms will satisfy the following requirements: enhancing the power system security through efficient use of limited generation and transmission assets, optimizing the utilization of limited natural resources, extending the lifespan of generations and transmission assets, prolonging the investment costs for adding new facilities, and reducing the operation costs for supplying loads. Li and Fu were also awarded a National Science Foundation grant to research the application of their algorithms in the U.S. to aid the aging system until more upgrades can be made to improve global energy sustainability.

Major Overhaul for Asian Taxis

Auto rickshaws are three-wheeled vehicles that are used primarily in Asian countries as taxis and to transport goods.

Despite their sleek design and inexpensive operation, auto rickshaws have become a nuisance in Indian cities because of their contribution to air and noise pollution.

A student-faculty team at IIT is making auto rickshaws a springboard for environmental consciousness in India. Currently, the team is building their first prototype of a solar-electric hybrid rickshaw and developing a design for a grid-connected solar-powered battery recharge station to charge its batteries in an environmentally friendly way.

Hybridizing Large and Working-class Vehicles

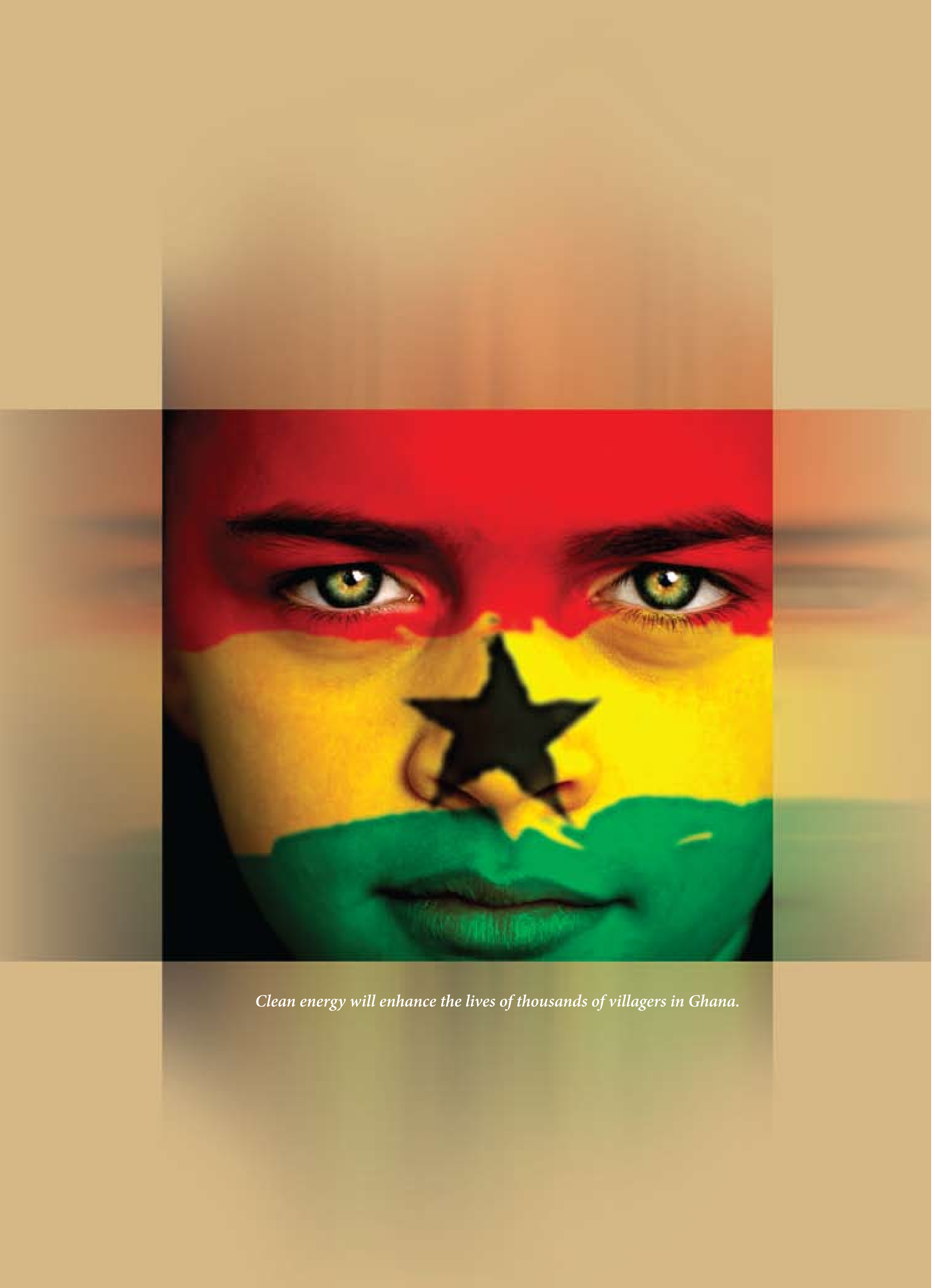
Can a Hummer—known as a symbol of excess and poor fuel economy—change from environmental offender to eco-savvy?

Professor Ali Emadi says "HECK" yes.

Thanks to researchers like Emadi, hybrid electric cars have been on the market for years and are steadily becoming a sought-after high-tech commodity. However, two groups of vehicles have long been ignored: large and working-class vehicles.

To address this need, teams at IIT have developed a hybrid electric system that is designed to retrofit—or add on to—large vehicles such as the Hummer and the military used HUMMVEE. The Hybrid Electric Conversion Kit (HECK) can be produced using off-the-shelf components and can be altered to hybridize other means of transportation.

Using plug-in hybrid technology, Emadi and his team are also transforming some less glamorous "working" vehicles that are in desperate need of change. They are currently using plug-in technology to hybridize mass transit and school buses to reduce emissions and provide a more economic form of transportation. Their efforts are helping United States citizens and governments to work together to improve the environment. Working prototypes of both types of buses have already been produced and are on pace to go to market development.



Clean energy will enhance the lives of thousands of villagers in Ghana.

ECE Alumnus Brings Clean Energy to Ghana

When Steve Tonissen (EE '70) talks about his experience with the people of Kasei, Ghana, you feel his passion and you want to help, even if you have never stepped foot on African soil.

Most of the village residents in Kasei are farmers, some are shopkeepers, and others are government workers. With only 2,300 people in the village, more than 550 are school-aged children. In Ghana, children can attend up to the equivalent of ninth grade for free, then they must pay to attend grades 10–13 and to go on to college.

An issue larger than money, however, is finding time to *go* to school. Kasei, like many villages, has no reliable source of electricity except for the power that runs to the school and hospital. The majority of the farm work is done by families during the day without technologically advanced equipment, making it more time consuming and labor intensive.

For less than $50 per person and with the support of his very good friends at BASIC, Tonissen is working to change the villagers' lives using hydroelectric and solar power. Kasei is abundantly sunny, with major aquatic resources. Tonissen estimates that with a single 5kW solar-powered generator or a low-head hydroelectric dam at the nearby river, the villagers could have one energy-efficient light bulb per household and enough power to enjoy basic necessities such as a refrigerator, radio, and Internet access.

The world has seen the economic stimulus that electricity can provide to remote areas, however, in the past it was often provided in environmentally irresponsible ways. Relief groups provided kerosene and diesel-powered generators, but the cost of fuel and the environmental impact of the generators have reduced their viability as an energy source. The solar and hydro systems that Tonissen's group will provide will use cost-free renewable resources, giving the villagers a long-term sustainable solution.

So far, the group has developed a library and computer facility, sent textbooks for the children, and is providing training for teachers. The next step is to alleviate labor demands on the farms so young villagers can continue in school and farmers can more easily tend to their crops. Once power is provided, the group can create a long-term farming plan with the villagers. They have purchased more than 650 acres of farmland to begin economic development of the village. The farm will likely implement solar- and hydro-powered microgrids to provide power to housing, farm buildings, and outlying structures on the property. The entire project will cost roughly $500,000. BASIC and Tonissen still need support to reach their goals and change the lives of the Kasei villagers. To find out how you can help, contact Tonissen at 312-342-8895 or stonissen@smartsignal.com.

Harvesting Human Power— No Plug Needed

Ever been stuck with a dead battery and no charger?
Energy scavenging can help.
IIT is harvesting energy from human motion
to give people the power they need—anytime, anywhere.

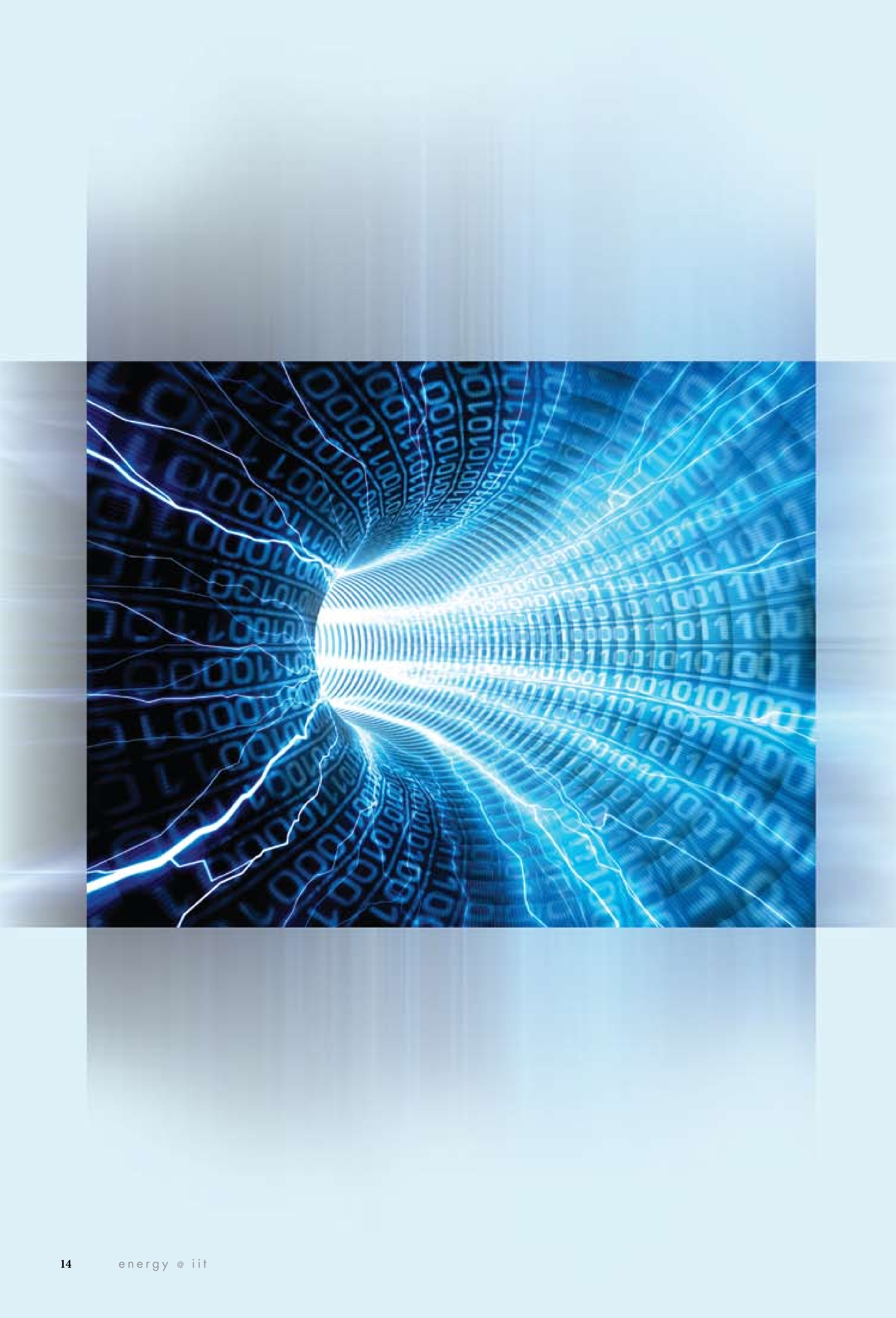
Energy scavenging is the collection of excess energy from environmentally friendly resources like vibration, human motion, or radio frequency, and using it to power a device. Professor Alireza Khaligh is investigating hybrid energy scavenging topologies to power wearable electronic devices such as cell phones, laptops, wireless internet devices, and music players.

"There is one actuation method being researched in academia; the heel strike method places electric material in the heel of your shoes and collects energy every time you step down," says Khaligh. "At IIT we are researching alternative human body motion methods such as using the up-and-down motion of one's center of gravity, horizontal movement of the foot, and joint motion."

Khaligh's team is using a hybrid of piezoelectric and electromagnetic harvesting to collect energy. With this method the team is building hybrid actuators for use in everyday devices that use motion to charge a small battery continually. The integrated system is about the same size as the battery packs used in most digital cameras and cell phones. In theory, as long as the user moves occasionally, they will never have a dead device.

Aside from commercial applications, one major benefactor of the technology is the military. Each soldier deployed on a 72-hour mission needs to carry an average of 27 pounds of rechargeable batteries to operate their equipment. With hybrid actuation energy scavenging, the need for bulky batteries would be eliminated, allowing soldiers to travel lighter.

"One of the most important impacts of the proposed research is significant reduction in grid-supplied energy," Khaligh says. According to him, the more than 200 million cellular phones in the United States use a combined total of approximately 14 MW of power. That is equivalent to the generating capacity of a small power plant! Imaging how much power we can save by applying human body motion energy to all our personal devices.



Riding the Wire

A revolution in broadband communications is about to happen with the advent of broadband over power lines giving Internet access to people in remote areas.

Currently, 60 percent of the world's population has access to power lines, but only 4 percent has access to broadband service. So, what if staying connected was as simple as plugging into the nearest power outlet?

Broadband over power lines (BPL) is the concept of injecting a broadband signal into power lines and delivering it to the consumer, who extracts it via a device plugged into the wall outlet. The socioeconomic impact of implementing BPL could be monumental, giving people in remote areas Internet capability, better access to information, and new avenues for social and economic change. However, there are a few challenges to overcome before this idea can become a reality.

Power plants generate electricity by burning fossil fuel or using nuclear reactors. Transmission substations take that energy and "step it up" into much stronger bundles of power so it can be transmitted over long distances. The stepped-up power is sent to power substations, where the voltage is stepped-down to more usable amounts and branched out to low voltage users like homes and businesses. The broadband signal would essentially be injected at the stepped-down medium voltage stage and ride the wire to the final low voltage destination, where the consumer extracts it.

The primary issue with this concept is that power lines are noisy. Every time a device is turned on or off, it sends a pop or click in the line that can interfere with the broadband signal. Also, a broadband signal cannot be sent through a transformer. IIT researchers are addressing this by using couplers to extract the signal before it reaches the transformer and sending it via wire around the transformer, through a bypass box, and back into the low voltage lines on the other side. To combat line noise and signal attenuation, researchers including ECE Professor Yu Cheng are working on ways to regenerate and amplify the signal during the bypass step.

Transporting Wind Energy

Wind energy is an abundant natural resource. However, it is harvested in sparsely populated areas and must be transported or stored to be used in major centers where it is needed most.

Professors Mohammad Shahidehpour and Zuyi Li are studying the means of transmitting wind power from windy states like the Dakotas to major power load centers in the central and eastern United States.

One of the most-debated issues with wind energy is its intermittency. Energy storage systems can overcome intermittency using technology like lead-acid batteries, flywheels, and pumped-storage hydro. Shahidehpour and Li are studying the use of large storage solutions to firm wind energy, or make it more evenly distributed over high and low wind periods.

Their concept, which is supported by a National Science Foundation grant, will use a pumped-storage hydro power plant design with two water reservoirs located at different elevations and connected by a penstock system. Electric energy is transformed into potential energy by pumping water from the lower to the upper reservoir. When energy is needed to supplement a low wind period, the water is released at a steady rate to power an internal generator. With this integration, the pump unit can offset wind power imbalances and avoid curtailments.

Integration of Renewable Energy

Comments from Paul McCoy (EE '72), president and co-founder of Trans-Elect

Trans-Elect is the first independent electric transmission company in North America. Organized in 1999 the company is making America's electric transmission grid more reliable by developing, building, and purchasing transmission systems and operating those systems efficiently to expand capacity and lower costs. Paul McCoy recently donated $500,000 to establish a scholarship for ECE students studying power engineering. His gift and strong support of the ECE programs at IIT are helping the department in its efforts to become a nationwide leader in electrical and computer engineering higher education.

"The emergence of large-scale renewable energy developments, plus a renewal of interest in nuclear power, require a fairly fundamental change in how we plan the grid of the future. Renewables will be a major part of the energy equation moving forward. Currently, much of the renewable development is driven by states mandating that a portion of the total energy consumed in that state be supplied by renewables as a matter of public policy to reduce the growth of carbon emissions. However, wind in particular is already cost competitive on an absolute basis with other generation technologies. Studies have shown that integration of wind up to a level of 10 percent of energy consumed is not much of a problem, and that 15 percent and higher penetrations are possible in portions of the system that are well interconnected. Europe is studying penetration levels of 30 percent! The key is a strong grid. With the advancements being made at IIT, we are on the road to more intelligent integration of renewables."

Wind-powered Skyscrapers—
Ambitious Engineering in the Windy City

There are many stories about how Chicago was nicknamed the Windy City, but ambitious architects and electrical engineers could give new reason to the blustery moniker.

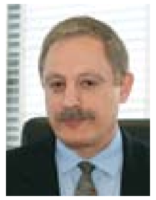
By integrating wind energy into the design of skyscrapers and bridges, engineers can harness the natural urban airflow of windy cities like Chicago, Toronto, and Manama in Bahrain, and help offset heavy city demands for energy.

Electrical and Computer Engineering Visiting Professors Yong Fu and Lei Wu are experts in wind energy and how it can be applied to the world around us. "Integrating wind energy into building design is an innovative step to perfecting power," Wu says. "Currently, we rely on rural wind farms to generate electricity then use transmission lines to send it where it is needed. As my colleagues and I are working to reform the transmission and grid systems, it is also necessary to rethink how energy can be generated and used in heavily populated areas to offset the demands on the current system."

Designs for wind-integrated structures have surfaced from famous engineers and newcomers alike who are pushing the world to think greener than before. One proposed example is the Clean Technology Tower by Adrian Smith + Gordon Gill Architecture, a Chicago-based firm. The tower is designed to harness renewable wind and solar power with wind turbines located at the building's corners and photovoltaic cells on a dome at the top of the building. At the apex of the building, where wind speeds are at their maximum, the domed double-roof cavity captures air, allowing for a large wind farm to help power the building.

Wind-integrated structures typically feed power directly to the grid, helping to power the businesses and homes inside. The twin towers of the Bahrain World Trade Center, shown here, are a primary example. Using the design of traditional wind towers, the shape of the structure channels the Persian Gulf airflow through three massive turbines. The turbines are each supported by an individual bridge spanning between the two towers. Connected to generators, the wind turbines feed power to the building grid, reducing the load on external power sources.

"Greenscrapers," or green skyscrapers, are already being built in Chicago. The eco-friendly 340 on the Park has integrated smart appliances and other intelligent energy savers, making it the first skyscraper in Chicago to meet Leadership in Energy and Environmental Design (LEED) requirements. Judging by the buzz from engineers around the city and at IIT, it won't be the last.


Shahidehpour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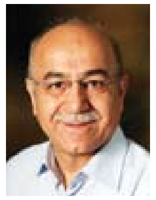
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ECE Power Professors at Illinois Institute of Technology

Mohammad Shahidehpour
Mohammad Shahidehpour is Carl Bodine Distinguished Professor and chair of the IIT Department of Electrical and Computer Engineering, where he has been a faculty member for the past 25 years. He is the author of more than 300 technical papers and five books on electric power systems planning, operation, and control. He is the recipient of several paper, faculty, and research awards including the 2007 IEEE/PES T. Burke Hayes Faculty Award in Electric Power Engineering. He has held several editorial positions and is currently the vice president of publication for IEEE/PES. Shahidehpour is an IEEE distinguished lecturer and continues to speak around the world on electricity restructuring issues.

Ali Emadi
Ali Emadi is director of the Electric Power and Power Electronics Center and Grainger Foundation Laboratories at IIT, where he has established research and teaching facilities as well as courses in power electronics, motor drives, and vehicular power systems. He is the founder, director, and chair of the board of the Industry/Multi-university Consortium on Advanced Automotive Systems. He is an academic leader and author of five books in the field of vehicular power and propulsion systems and electric, hybrid electric, and plug-in hybrid electric vehicles.

Alexander Flueck
Alexander Flueck's research interests focus on power system stability and control. He is currently developing robust and efficient computational tools that will assist power engineers in planning and operating large-scale electric power systems, while emphasizing security and competitiveness. The goal of Flueck's research is to numerically compute the safe operating region of electric power systems under varying load/generation levels and facility outage contingencies. He is actively working with industry leaders to implement his research and advising on several industry projects.

Alireza Khaligh
Alireza Khaligh is director of the Energy Harvesting and Renewable Energies Laboratory in the ECE department. Khaligh is author/coauthor of more than 50 papers, books, and invention disclosures. His major research interests include modeling, analysis, design, and control of power electronic converters, energy scavenging/harvesting from environmental sources, electric and hybrid electric vehicles, and design of energy-efficient power supplies for battery-powered portable applications. He is currently developing Mesoscale and MEMS-scale hybrid topologies to power wearable electronic devices as well as implantable medical devices.

Mahesh Krishnamurthy
Mahesh Krishnamurthy's research interests include embedded systems for renewable energy and vehicular applications, and power electronics for vehicular applications. He is the most recent addition to the ECE power engineering faculty.

Zuyi Li
Zuyi Li's research focuses on market operation and wide-area protection of electric power systems, including load forecasting, price forecasting, price-based unit commitment, security-constrained unit commitment, arbitrage in electricity market, market power analysis and risk management, ancillary services auction, and transmission pricing. He recently coauthored a book on market operations in electric power systems.


Wiedman


Williamson


Zhou


Choi


Fu


Rodriguez


Wu

Hasan Shanechi
Hasan Shanechi's research is in nonlinear and intelligent systems, and he has been especially active in power system dynamics and security. He has done extensive research in analyzing stressed power systems and explaining their behavior when heavily loaded, and has done research in power system planning and maintenance scheduling.

Thomas Wiedman
Thomas Wiedman retired from ComEd/Exelon in 2003 and formed Wiedman Power System Consulting Ltd. He serves as an electrical engineering consultant for North American Electric Reliability Corporation, NERC, analyzing power system disturbances and participating in standards making activities. He also teaches courses at IIT in protective relaying and power system protection.

Geoffrey Williamson
Geoffrey Williamson's research interests include system identification and parameter estimation as applied in the areas of signal processing, control, and biomedical applications; control of power electronic systems; and analysis of bio-acoustic signals. He has served as associate dean for academic affairs in IIT's Graduate College and as graduate program director for the Department of Electrical and Computer Engineering. He is a senior member of the Institute of Electrical and Electronics Engineers and a member of Eta Kappa Nu and Tau Beta Pi.

Chi Zhou
Chi Zhou researches wireless communications, mobile networks, power control/resource allocation, and integration of heterogeneous networks. She is currently advising on ZigBee technology as part of the Perfect Power Prototype at IIT Main Campus.

ECE Visiting Power Professors

Jaeseok Choi
Jaeseok Choi is a visiting professor from Gyeongsang National University in Korea. His research interests include fuzzy applications, probabilistic production-cost simulation, reliability evaluation, and outage cost assessment of power systems. Specifically, his research focuses on development and extension of methodology at load points of composite power systems. He has been a professor at Gyeongsang National University since 1991.

Yong Fu
Yong Fu's research interests include economics and control of electrical power systems, modeling and optimization of large-scale power systems, power system security and reliability, electricity equipment maintenance scheduling, generation and transmission planning, and power market design. He recently coauthored a book on operation and control of electric energy systems.

Fernando Rodriguez
Fernando Rodriguez's research interests include digital and analog controller design of high-performance servo systems, modeling and design of power electronic converters, and analysis of hybrid electric vehicles (HEV). His research work with HEVs focuses on the system integration and management of vehicular electro-mechanical subsystems.

Lei Wu
Lei Wu received his Ph.D. in electrical engineering from Illinois Institute of Technology and is now a visiting research faculty member. His research interests include power system restructuring, decision analyses, stochastic optimization, and reliability. He recently coauthored a book on risk management in restructured electric power systems.

PERFECTING POWER AT IIT

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