IEEE Standards Education e-Magazine

The IEEE Standards Education e-Magazine A publication for those who learn, teach, use, deploy, develop and enjoy Standards! Sponsored by the Standards Education Committee IEEE is committed to: promoting the importance of standards in meeting technical, economic, environmental, and societal challenges; disseminating learning materials on the application of standards in the design and development aspects of educational programs; actively promoting the integration of standards into academic programs; providing short courses about standards needed in the design and development phases of professional practice. Serving the community of students, educators, practitioners, developers and standards users, we are building a community of standards education for the benefit of humanity. Join us as we explore the three fundamental dynamics of standards--technology, economics and politics, and enjoy our feature articles about the use, deployment, implementation and creation of technical standards.

The IEEE Standards Education e-Magazine

Smart Grid Issue, First Quarter 2012, Vol. 2, No. 1

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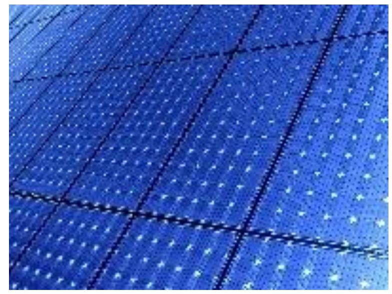

A publication for those who learn, teach, use, deploy, develop and enjoy Standards!

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- promoting the importance of standards in meeting technical, economic, environmental, and societal challenges;
- disseminating learning materials on the application of standards in the design and development aspects of educational programs;
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Serving the community of students, educators, practitioners, developers and standards users, we are building a community of standards education for the benefit of humanity.

Learn more about the three fundamental dynamics of standards--technology, economics and politics, and enjoy our feature articles about the use, deployment, implementation and creation of technical standards.

What are Standards?

Technical standards are formal documents that establish uniform engineeering or technical criteria, methods, processes and practices developed through an accredited consensus process.

Standards are:

- developed based on guiding principles of openness, balance, consensus, and due process;
- established in order to meet technical, safety, regulatory, societal and market needs;
- catalysts for technological innovation and global market competition.

Knowledge of standards can help facilitate the transition from classroom to professional practice by aligning educational concepts with real-world applications.

Join us as we explore the dynamic world of standards!

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Letter from the Editor-in-Chief

Yatin Trivedi

Happy New Year! Welcome to 2012. Times are changing. The power industry, it is said, is going through some fundamental changes. No, the movement of electrons is still required to produce the electricity and we are not changing the voltage or frequency at the power outlets in our homes, offices or factories, nor are we changing the traditional model of power grid – generation, transmission, distribution and consumption. In fact, each of these components of the power grid is continually upgraded in response to technology advances, environmental concerns and consumer as well as industry demands. Not only are there more ways power is being generated, transmitted, distributed and consumed but also monitored for reducing wastage and improving efficiency with the help of electronic communication and automation. In short, everything related to power is becoming complicated, but smarter!

Smart Grid appears to be the big focus in power industry these days and a lot of new information has been published by many sources to educate you on what Smart Grid is and how it works. In fact, we posed the following two questions to some industry experts: How do you plan on retraining the current workforce, and how you plan to educate the new generation on Smart Grid specifically in the context of Smart Grid standards.

Dr. George Arnold, national coordinator for Smart Grid at the National Institute of Science and Technology (NIST) and past President of the IEEE Standards Association (IEEE-SA) has shared his insights about the challenges of preparing a skilled workforce familiar with Smart Grid standards and about government grants under the American Recovery and Reinvestment Act. He also strongly recommends industry-university collaboration. Dr. Arnold was an advisor to MIT's research report "The Future of the Electric Grid". You will find a link to this interdisciplinary study in the Resources section. If you have only a limited time to browse through this comprehensive report, pay special attention to Chapter 9: Data Communication, Cybersecurity and Information Privacy to gain quick insights into the applicable standards and their importance to practicing engineers, administrators, and consumers.

At the December 2011 meeting of the IEEE-SA Standards Board, I accidentally met Dr. Dick DeBlasio, Chief Engineer at the National Renewable Energy Laboratory (NREL), Chair of IEEE 2030 and recipient of the prestigious IEEE Charles Proteus Steinmetz Award. I can only describe it as 'being at the right place at the right time;' just plain lucky! Dr. DeBlasio shared a wealth of information about Smart Grid standards through articles that he he and his team have published. These articles are informative about current Smart Grid interoperability and interconnection standards and those that are in progress.

Contrary to popular thought, Smart Grid is not exclusively a US initiative and the standards are not only meant for US industry. Our friends from Korea, Dr. Heesung Ahn, Senior Researcher at Korea Electrical Engineering & Science Research Institute (KESRI), Convener of WG2 in IEC CISPR SC B, and Prof. Joong-Geun Rhee, from Hanyang University, Chairman of Korean National Committee for IEC/CISPR & TC77 have shared information about how the Korean power industry sees the importance of Smart Grid standards in academia.

Professor Liuqing Yang from Colorado State University at Fort Collins writes about the research work of three of her Ph.D. students related to Smart Grid standards. All three projects were recently funded by Standards Education Committee (SEC) under the Student Application grants.

In the Resources section you will find links to a wealth of information – a list of IEEE Smart Grid standards (approved and in progress), links to articles published in The Institute, the MIT report referenced above, Dr. DeBlasio and his team's articles, and upcoming conferences. For those aspiring to get involved in research, we have a list of research labs at various universities. If your university or institute is involved in Smart Grid research and would like your lab to be listed as a resource, please contact us.

Thanks to Ms. Stacey Masucci, Acquisitions Editor at Cengage Learning, we had access to Smart Grid Dictionary Plus – a guide that every student and every experienced engineer should get their hands on. It is like a self-study guide; "Cliff's Notes" for Smart Grid, or "Smart Grid for Dummies", if you like. Editorial Board member and reviewer Dr. Amin Karim gives you a great synopsis of the contents and explains why this one is not a paper weight but rather a real, everyday reference for all engineers. Enough said. Read the review and get the Dictionary.

So how is the industry preparing to transition the current workforce to the required skills for these advances and where does the standards education fit in? Take a survey put together by Don Heirman and tell us about your views on Smart Grid standards education. If you prefer to have a descriptive dialog, here are a few questions to get this public dialog going:

> If you are a student, we would love to hear how you (and your university) are preparing yourself for employment in the Smart Grid industry. Is Smart Grid a new curriculum in EE department? Perhaps a new elective track? How are you taught about the Smart Grid standards? Is there a particular faculty member mentoring student projects based on Smart Grid Standards? Is the Career Center hosting Smart Grid Day and inviting companies to recruit? Are there summer or semester internships available? Are there research grants for standards based projects?
>
> If you are a professional in the field, how are you keeping your skills current on Smart Grid standards? Are you offered continuing education courses by your employer? Are you encouraged to participate in standards activities? Are you given

access to IEEE Smart Grid Standards? Do you make use of Smart Grid standards? Which ones? Are you encouraged to teach Smart Grid standards to your colleagues? Do you participate in compliance testing with standards of your products?

There are just so many questions and no simple answers. We would love to share your insights and experiences with the reader community so we all can be better prepared for the Smart Grid revolution. We will publish your comments and survey results in future issues of this eZine.

I would also like to bring to your attention a wonderful collaboration between IEEE-SA and Rutherford Appleton Laboratory's EuroPractice project. Dr. John McLean, Head of Microelectronics Support Center at the lab, explains the EuroPractice project and why this collaboration is important for universities and research institutes engaged in microelectronics. We look forward to long and productive collaboration between our two organizations.

In this issue, we continue our interview with IEEE-SA President Mr. Steve Mills, exploring the connection among technology, standards, education and economics. Of course, we hope you also find our regular features such as Best of Student Application Papers, list of standards, books and conferences on Smart Grid interesting and informative. As always, we look forward to your feedback on this issue and your suggestions for standards education topics to cover in future issues.

Finally, special thanks to Editorial Board member Dr. Don Heirman who knows just about everyone around the world working in the Smart Grid standards arena. His personal connections are largely responsible for the very informative contents of this issue. You can be sure he will bring you more information about Smart Grid standards education from around the world in future issues of the Standards Education eZine. Thank you, Don!

The IEEE Standards Education eZine Editorial Board welcomes your comments and suggestions. Please write to us at: ezine-eb@listserv.ieee.org.

About the Editor-in-Chief

Yatin Trivedi, Editor-in-Chief, is Director of Standards and Interoperability Programs at Synopsys. He is a member of the IEEE Standards Association Standards Board (SASB), Standards Education Committee (SEC), Corporate Advisory Group (CAG), New Standards Committee (NesCom), Audit Committee (AudCom) and serves as vice-chair for Design Automation Standards Committee (DASC). For 2012, Yatin was appointed as the Standards Board representative to IEEE Education Activities Board (EAB). He represents Synopsys on the Board of Directors of the IEEE-ISTO and on the Board of Directors of Accellera. He represents Synopsys on several standards committees (working groups) and manages interoperability initiatives under the corporate strategic marketing group. He also works closely with the Synopsys University program.

In 1992, Yatin co-founded Seva Technologies as one of the early Design Services companies in Silicon Valley. He co-authored the first book on Verilog HDL in 1990 and was the Editor of IEEE Std 1364-1995™ and IEEE Std 1364-2001™. He also started, managed and taught courses in VLSI Design Engineering curriculum at UC Santa Cruz extension (1990-2001). Yatin started his career at AMD and also worked at Sun Microsystems.

Yatin received his B.E. (Hons) EEE from BITS, Pilani and the M.S. Computer Engineering from Case Western Reserve University, Cleveland. He is a Senior Member of the IEEE.

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Importance of Standards

In the second of a three-part interview, Steve Mills, President of the IEEE Standards Association is back with our eZine Editor-in-Chief Yatin Trivedi to discuss how industry can help with continuing education by engaging with the standards community.

Part two in the three-part series (4:59)

Revisit Part one in a three part series (5:53)

Videos will launch in You Tube.

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Europractice partners with the IEEE to promote Standards Education

by Dr. John A. McLean

First Quarter 2012

Europractice is a well established European Commission supported service that provides an infrastructure for universities and research laboratories engaged in microelectronics teaching and research that allows them access to industry standard design tools and routes to fabrication coupled with advanced train-the-trainer courses. This common infrastructure facilitates inter-university cooperation and allows the academic institutions to conduct research that is relevant to the needs of industry, and to produce graduates whose skills are well matched to industry's requirements.

The origins of Europractice can be traced back to 1989 and the start of the forerunning and ground breaking pan-European project Eurochip. The initial goal was to provide 50 selected universities with cost-effective access to commercial Electronic Design Automation (EDA) tools and to prototype integrated circuits from commercial foundries fabricated via a multi-project wafer (MPW) service. Today, more than 20 years later, the project has evolved into Europractice and supports over 650 academic institutions from 44 countries in the EMEA (Europe, Middle East and Africa) region.

STFC Rutherford Appleton Laboratory, a national research laboratory in the UK, operates and manages the EDA tool portfolio within Europractice. The design tool portfolio features best in class tools from the world's leading EDA vendors that collectively offer extensive functionality to address a wide range of design methodologies ranging from embedded system design, through all types of ICs, to semiconductor device modelling. STFC works in close cooperation with imec of Leuven, Belgium and Fraunhofer IIS of Erlangen, Germany who provide access to affordable IC and MEMS prototypes through the Europractice MPW service.

Virtually all of the postgraduate students entering industry after completing microelectronic or electronics system design orientated research in European universities have used EDA tools and methodologies made available by the Europractice project and supported by STFC Rutherford Appleton Laboratory. Similarly the majority of undergraduate students graduating from European universities have exposure to current design methods in their course work or benefited indirectly from their lecturers having first-hand practical experience of modern design techniques and tools than would otherwise have more difficult without the services and support structure of Europractice.

STFC Rutherford Appleton Laboratory, with its long history of high quality services and links to nearly all European Universities active in microelectronics and electronics system design is pleased to collaborate with the IEEE Standards Association to promote standards education and is very well placed to help train faculty members of virtually all of the academic institutions in Europe engaged in microelectronic design and electronic system design.

Dr. John A. McLean joined the Science and Technology Facilities Council Rutherford Appleton Laboratory in 1979 after graduating with a BSc in Electrical and Electronic Engineering and a PhD in Computer Aided Design. He has managed a range of electronic system and microelectronics projects, is currently Head of the Microelectronics Support Centre and has managed the Europractice and former Eurochip design tool activity since it was launched in 1989.

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Smart Grid: Standards and Education

by Dr. George W. Arnold, Eng. Sc.D

National Coordinator for Smart Grid Interoperability, National Institute of Standards and Technology

First Quarter 2012

Affordable and reliable electric power is fundamental to modern society and the economy. With the pervasive application of electronics and microprocessors, reliable and high quality electric power is becoming increasingly important. While the grid has benefited from many innovations over its history, in some respects its basic design is little changed from its inception over a hundred years ago. Modernization of this aging system has become a major priority for many countries around the world. The “Smart Grid” refers to the integration of advanced information, sensing and control, and communications technologies into the power system. The Smart Grid will operate more efficiently, reliably and securely, support high penetration of intermittent renewables and other new technologies such as storage and electric vehicles, and provide consumers with new tools to manage their energy use and reduce costs. Through the application of these technologies, the grid of the future will operate much differently than it does today. Planning, engineering and operation of the grid will require new skills within the utility industry. In addition, technical professionals in the IT, data communications and control systems sectors will require an understanding of the unique attributes of power systems in order to effectively apply these technologies to the grid.

Transitioning the existing electric infrastructure to the Smart Grid requires an underlying foundation of standards and protocols that will allow this complex "system of systems" to interoperate seamlessly and securely. Technical standards for the Smart Grid are under development by over 20 standards development organizations (SDOs), most of them international in scope, including IEEE, IEC, ISO, ITU-T, IETF, among others. IEEE has more than 100 published standards and standards in development relevant to the Smart Grid. IEEE is working in partnership with the National Institute of Standards and Technology (NIST) which is developing a standards roadmap and conformance testing/certification framework for the Smart Grid, and is collaborating with other global standards bodies to effectively facilitate standards coordination and to ensure the intensifying Smart Grid movement's success.

Over the next five years, approximately 45 percent of engineers in electric utilities will be eligible for retirement or could leave engineering for other reasons. If they are replaced, there would be a need for over 7,000 power engineers by electric utilities alone: two or three times more power engineers may be needed to satisfy needs of the entire economy. New hires into the industry will not only need to be knowledgeable in the traditional power engineering disciplines, but will also require knowledge in information technology, data communications, and cybersecurity. The emerging standards applicable to the Smart Grid must be incorporated into technical institute and university curricula whose graduates are hired by utilities. A number of new programs have been established to fill this need, some of which have been funded by the Department of Energy's $100 million Smart Grid workforce grants program created under the American Recovery and Reinvestment Act. One example is a new interdisciplinary program "Strategic Training in Networking for Power Systems" at the University of Colorado Boulder. Since jobs may also be filled by retraining individuals transitioning from other careers, continuing education programs are needed in addition to courses offered as part of college and university degree programs. Knowledge of the standards underpinning the operation of the Smart Grid will be key. The academic community must be actively engaged in education about standards for the Smart Grid by first training its own faculty and then imparting that knowledge to students who will make up the new generation of workforce. It is also extremely important that this new generation of workforce be trained in both the theory (concepts) underlying the standards and the implementation (hands-on labs and projects) in order to deploy and maintain all aspects of the Smart Grid in the real world.

The IEEE is well-positioned to lead the development of education programs to train the workforce needed to plan, engineer and operate the Smart Grid based on open standards and 21st century technologies.

Dr. George W. Arnold joined the National Institute of Standards and Technology (NIST) in September 2006 as Deputy Director, Technology Services, after a 33-year career in the telecommunications and information technology industry. He was appointed National Coordinator for Smart Grid Interoperability in April 2009. He has been responsible for leading the development of standards underpinning the nation's Smart Grid. In October 2011, Dr. Arnold added an additional role as Director of the Cyber Physical Systems Program within NIST's Engineering Laboratory (EL). Anticipating and meeting the measurement science and standards needs for technology-intensive manufacturing construction, and cyber-physical systems in ways that enhance economic prosperity and improve the quality of life, EL promotes U.S. innovation and industrial competitiveness in areas of critical national priority.

Dr. Arnold served as Chairman of the Board of the American National Standards Institute (ANSI), a private, non-profit organization that coordinates the U.S. voluntary standardization and conformity assessment system, from 2003 to 2005. He served as President of the IEEE Standards Association in 2007-2008 and is currently Vice President-Policy for the International Organization for Standardization (ISO) where he is responsible for guiding ISO's strategic plan.

Dr. Arnold previously served as a Vice-President at Lucent Technologies Bell Laboratories where he directed the company's global standards efforts. His organization played a leading role in the development of international standards for Intelligent Networks and IP-based Next Generation Networks. In previous assignments at AT&T Bell Laboratories he had responsibilities in network planning, systems engineering, and application of information technology to automate operations and maintenance of the nationwide telecommunications network.

Dr. Arnold received a Doctor of Engineering Science degree in Electrical Engineering and Computer Science from Columbia University in 1978. He is a Fellow of the IEEE.

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Smart Standards for the Smart Grid

IEEE Standards Association helping to create a roadmap for the grid's infrastructure

By IVAN BERGER

This article first appeared in the December 2010 issue of THE INSTITUTE, the member newsletter of the IEEE.

"The U.S. power-grid infrastructure is a century old, but its technology is mainly from the 1950s," notes Dick DeBlasio, chief engineer at the U.S. Department of Energy's National Renewable Energy Laboratory, in Golden, Colo. Many other countries' grids also go back to the 1950s, if not earlier. Despite a recession-inspired lull in power demand, and some slowing of demand growth through adoption of green technologies, the world's power grids need to be beefed up to carry more power—and smartened up for greater system-wide efficiency. Doing that takes new technologies. It also calls for lots of standards to harmonize everything.

That's where IEEE comes in.

DeBlasio, an IEEE life member, is IEEE's smart-grid liaison to the National Institute of Standards and Technology (NIST). The IEEE Standards Association, along with other groups, is collaborating with NIST to create the Smart Grid Interoperability Standards Roadmap. It identifies the short- and long-term plans under way for developing the grid's architecture and the standards and infrastructure that will be needed.

The smart grid involves modernizing the generation, delivery, and use of electricity. "I consider it a system of interconnection and interoperability among distributed electric power sources such as solar, wind, other generation technologies, and storage—with two-way power flow and communications between power sources and end loads," says DeBlasio.

DeBlasio chairs IEEE's P2030 standards working group (which is developing guidelines for smart-grid interoperability) and IEEE Standards Coordinating Committee 21 (which sponsors the standard known formally as the IEEE P2030 Draft Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation With the Electric Power System and End-Use Applications and Load).

"Most of our power-side standards are systems-level," DeBlasio says, "so the guide is intended to work with NIST's smart-grid road map. It's easier to develop standards when you have a guide like this than if you have to build from scratch each time."

More than 100 IEEE standards apply to the smart grid, and about three dozen more are in development. Here are some of the standards being developed.

COMMUNICATIONS

What is expected to make the smart grid smart is its ability to carry information and monitor itself, pinpointing outages and problems, telling controls when to run appliances most economically, and using weather information to predict the output of wind and solar installations.

"Transformers, relays, and so on have the potential to be Internet nodes you can query as to status, so communications protocols will be required," says Chuck Adams, president of the IEEE Standards Association.

Using the grid as a communications link for power management could make it viable for general narrowband and broadband communications, especially in rural areas that are connected to the grid but lack broadband links. That would involve IEEE 1901 for communications over power lines.

"The long-term goal is not just two-way power but also two-way communications and two-way IT management," says Adams, an IEEE senior member. "In particular, we need to look at integration of regenerative energy, because the power generated by sources such as wind varies and because mismanagement can bring down the system."

An IEEE standard addresses that: IEEE 1547, on interconnecting distributed power-system resources. IEEE is working with the International Electrotechnical Commission's (IEC) Technical Committee 8 to make IEEE 1547 a joint IEC/IEEE product.

Power companies need to be able to plan when they'll run their stationary power plants, which take a while to bring up to speed, and when they can count on wind power, Adams adds. Another challenge is what to do with generated energy when there's not enough demand, so IEEE is getting into standards for managing energy storage.

In the consumer electronics arena, IEEE is looking at interoperability and communications between appliances and the grid. "When you plug in a new refrigerator, the maker will know it's online, be able to detect and address problems, and update the software used to run it," Adams says. And the appliance will know to schedule power-hungry operations such as defrosting for the hours when power cost is low, he adds. Such intelligent appliances are already being introduced.

Then there's the IEEE P2030.1 for electric vehicles, which covers two-way power flow and communications between plugged-in electric cars and the grid.

The more interconnected a system is, the greater its vulnerability to mischief. "By modernizing communications, we create openings [for hackers]," DeBlasio says. "This could open up possibilities of upsetting the communications system and, therefore, the grid." The NIST smart-grid interoperability panel has a subpanel considering the grid's vulnerability, and the P2030 working group is addressing it as well.

COORDINATION
Certainly, no single standards community or standards organization will be able to do all that's required. IEEE will probably need to partner with other organizations. For example, communications via the grid are likely to use Internet Protocol, Adams notes, and that probably will involve the Internet Engineering Task Force.

Adams adds that the European Telecommunications Standards Institute is looking at communications infrastructure, as well as such standards as GSM and its 3G and 4G extensions. IEEE is strong in that area, with networking standards such as the IEEE 802 wireless standards.

IEEE also has relationships that allow joint standards development with the International Organization for Standardization and IEC.

"And as a member of the International Telecommunication Union, IEEE can bring proposals and input to their projects," Adams says. "Most of the industry today is global, so industry wants to be able to develop and manufacture products that can be used worldwide."

THE INSTITUTE is the member newspaper of the IEEE. Available monthly as a Web publication, it is mailed quarterly to all members of IEEE.

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Flexible Education for Smart Grid

By Heesung Ahn, Chairman of WG2 in the Korean National Committee for IEC/CISPR Steering Committee B, and Joong-Geun Rhee, Chairman of the Korean National Committee for IEC/CISPR & TC77

First Quarter 2012

Introduction
From a viewpoint of electrical power, there are several differences between a conventional power system and a smart grid system in control, power generation, and communication. For example, the control (or electric current flow) of the conventional electrical power system is unidirectional (or one way). On the other hand, a smart grid system is bidirectional. Whereas the conventional power system has a bulk power generation system only, the smart grid system includes a distributed power generation system together with a bulk generation system. Smart grid is a new concept which started from renewable energy and micro grid. Electrical engineers say that smart grid consists of two major systems; power systems and information and communications technology (ICT) systems. A major aim of smart grid is to reduce CO2 (carbon dioxide) generation. To reduce CO2, renewable energy sources and ICT technology are essential. By the Gaia hypothesis this means that mass energy generation with environmental destruction can't be allowed for human beings and the earth itself.

Smart grid is similar to an internet. In the early days of the internet, information could be produced and circulated only by big organizations. However the internet caused a revolution of access to the information. Nowadays everybody can produce information and distribute it freely (at no cost). Similarly, smart grid will trigger the energy revolution. In the future, we expect that everybody can produce energy and trade it. Smart grid will become important as an infrastructure for energy circulation and trade.

The current situation of smart grid

Smart grid has just started. Thus there are a lot of issues to be solved for an actual implementation. The most essential issue is how to guarantee 'interoperability' among the large amount of equipment and systems. The International Electrotechnical Commission (IEC) defines 'interoperability' as follows: each "box" can connect with all the others and that those "boxes" are interchangeable. However, what clearly needs to be defined are:

- All the different elements of the system that need to speak the same language without the need for translators to achieve optimal speed for information exchange.
- On a systems management level: what information is fundamental, which systems need to communicate, and how this information needs to be routed.
- On the physical level: the way the information needs to be transported (wires,cables, Internet, WiFi).

Smart grid has to clear the above interoperability issues because large quantities of equipment must interact intimately. (http://www.iec.ch/smartgrid/challenges/).

Today each group of stakeholders for smart grid is emphasizing their own focus. However, only few commercial products related to smart grid - electrical vehicle, electrical charger – have entered the markets. Therefore, many people still don't recognize the value, and have doubts about, the success of smart grid. What will happen to us in the near future? We raise a figurative example as follows to show the analogy:

There are two ways to go about the construction of a tunnel for cars. One way is to decide the tunnel size and the car size can be decided afterwards based on the tunnel size. The other way is the opposite way, where the car size is determined first and tunnel size is determined based on the car size. Today, there are few cars in smart grid. Thus we must decide the tunnel size first as a guideline.

Standards

Standards can simply be described as a same ruler or common level. But many standardization organizations (IEC, ISO, ITU-R, IEEE, etc.) and groups are engaging in the standardization activities for smart grid. Each standardization group is developing its own standards. But these standards are at many different levels that do not fit together and therefore pose a serious problem for interoperability certification. Also each group of stakeholders asserts its own interests. For example, a manufacturer might say that the global standard for smart grid is first. After the global standard, they can make products to fulfill interoperability. Another group may assert that smart grid products are first and then related standards can be easily developed. Under this situation, the IEC recommends that guidelines based on the related current standards should be developed at first.

Education

Smart grid is at an incubating stage for the industry. Therefore it is difficult to know how many experts are necessary and what kinds of curricula are needed. Many organizations and universities in the world have the same difficulty. In the incubating stage of smart grid, the aim of education is focused on how to train students and engineers as qualified experts during a specific period. Of course, education courses will respond to the demand of experts from the industry. To achieve this aim, a flexible education system may be required. 'Flexible' means a quick response for the demand of education curriculum, trainee, training organization, etc. The promotion of knowledge considering related standards is most effective. That means project-based education with a reward may be the best way for training and educating new experts. (An IEEE Standards Education

Committee Student Application Paper grant is one example. http://ieee-elearning.org/outreach/mod/book/view.php?id=315&chapterid=17.)

Conclusion

To achieve the success of smart grid, interoperability is the most important issue to be solved. Many standardization organizations show interest in providing a solution to this issue. In the current situation, there are only a few commercial products related to smart grid. Before the industry is activated in high capacity, global guidelines should be developed. In parallel, a flexible education system is required to respond to the demands of experts from the industry. The project-based education program considering related standards is the best way to produce high quality results.

Joong-Geun Rhee is a Professor in the Electrical Engineering Department, Hanyang University, Seoul, South Korea, and Chairman of the Korean National Committee for IEC/CISPR & TC77. Professor Rhee, Joong-Geun was born in Seoul, South Korea, on 21 April 1945. He received the B.S. degree in electrical engineering from the Seoul National University in 1967. He also received the M.S. and Ph.D. degrees in electronic engineering from the University of South Florida, Tampa, FL, USA, in 1973 and 1979, respectively. From 1979 to 1988 he worked at the ADD (Agency for Defense Development, Ministry for Defense) as a Sr. Researcher and a Project Manager. From 1990 to 1991, he was the first president of the Korea Electromagnetic Engineering Society. Since 1988, he has been a professor in the E.E. Department at the Hanyang University. His research is mainly devoted to EMI/EMC, Antennas, and Microwave components, etc.

Heesung Ahn is Senior Researcher at the Korea Electrical Engineering & Science Research Institute (KESRI). Dr. Ahn received the B.S. in Electrical Engineering at Seoul National University, Seoul, Korea, and the M.S. and the Ph.D degrees in Electrical Engineering at Saga University, Saga Prefecture, Japan. He has been Convener of WG2 in IEC/CISPR Steering Committee B since October 2008, Chairman of WG2 in the Korean National Committee for IEC/CISPR Steering Committee B since 2009, and Convener of WG1 in IEC/CISPR Steering Committee since October 2011. He received the IEC 1906 Award in 2011.

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Advancing Interconnection and Interoperability Education through Standards Development and Technology Transfer

By Richard (Dick) DeBlasio
Chief Engineer, National Renewable Energy Laboratory, IEEE SCC21 Chair

First Quarter 2012

Interoperability is one of the greatest challenges facing the modern electric power system as a multitude of technologies, systems, and devices will need to securely and effectively talk to each other in order to achieve an end-to-end intelligent grid. The very nature of adding information and communications technology to the electric power system (grid) and seamlessly linking legacy and next-generation systems and applications, making everything work together intelligently and securely, is a daunting task, yet critical to the success of the fully interconnected, and interoperable grid with application loads.

Early to recognize the need for Smart Grid interoperability, the U.S. Department of Energy (DOE) Office of Electricity Delivery and Energy Reliability (OE), tasked NREL engineers to facilitate and lead the way in the development of targeted interoperability standards. Through these efforts ,in May 2009, the Institute of Electrical and Electronics Engineers (IEEE) announced a DOE/NREL-supported Smart Grid standards development initiative for bringing together the power engineering, communications, information technology, and related industries with the IEEE project approval of the IEEE P2030 Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS) and End-Use Applications and Loads (http://www.nrel.gov/eis/smart_grid.html).

Through the decades of support from the DOE, NREL has provided leadership and support for research, testing, and standards development for distributed renewable electric technologies and the electric power systems as far back as 1979.

In 1979, NREL (formerly SERI) founded IEEE Standards Coordinating Committee 21 (SCC21) to sponsor and oversee the development of standards in the areas of fuel cells, photovoltaics, dispersed generation, and energy storage. In June 1998, the IEEE Standards Board expanded the responsibilities of IEEE SCC21 to include all distributed generation and energy storage.

In 1999, IEEE SCC21 initiated IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems. From its inception, the IEEE Std 1547 development activity moved forward on a fast-track basis with unwavering support from industry, utilities, and general interest groups and individuals. The development of IEEE Std 1547 included arduous debate and scrutiny by hundreds of dedicated and experienced individuals. The standard was approved by the IEEE Standards Board in June 2003. The names of 444 work and ballot group individuals appear in the front of the standard.

IEEE Std 1547™ is the primary American National Standard for interconnection and has been used in federal legislation and rule making, state public utility commission deliberations, and the formulation of technical requirements for interconnection agreements by utilities nationwide, thus consolidating a multitude of individual requirements from many utilities. It is the only systems-level technical standard of uniform requirements and specifications universally needed to interconnect distributed resources with the grid. The approval of this standard has had a significant effect on how the energy industry does business and it continues to influence the way the electrical distribution systems operates. It also ensures that major investments in technology development by the federal government and industry will result in real-world applications. IEEE Std 1547 has matured into a series of published standards and evolving projects that remain in the forefront and are applicable to existing and ongoing Smart Grid initiatives. Some have reached completion while others are still very active.

The IEEE SCC21 1547 series of existing, published standards are:

- IEEE Std 1547™-2003 (reaffirmed 2008), IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems;
- IEEE Std 1547.1™-2005 (reaffirmed 2011), IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems;
- IEEE Std 1547.2™-2008, IEEE Application Guide for IEEE Std 1547™, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems;
- IEEE Std 1547.3™-2007, IEEE Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems;
- IEEE Std 1547.4™-2011, Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems.

The IEEE SCC21 1547 series of standards development projects that are currently underway are:

- IEEE P1547.5™, Draft Technical Guidelines for Interconnection of Electric Power Sources Greater Than 10 MVA to the Power Transmission Grid (no ballot date established);

- IEEE P1547.6™, Draft Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Network (passed, publication scheduled for September 2011;

- IEEE P1547.7™, Draft Guide to Conducting Distribution Impact Studies for Distributed Resource Interconnection (no ballot date established;

- IEEE P1547.8™, Draft Recommended Practice for Establishing Methods and Procedures the Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Standard 1547 (no ballot date established).

In addition, IEEE Std 1547 has recently been adopted as an IEC (International Electro Technical Commission) publically available standard (information document) and IEEE SCC21 has agreed to develop an IEEE IEC dual logo international standard that is encouraged by industry and supported by DOE. Coordination will be with IEEE SCC21 and IEC TC-8. This effort is unique and underway since no other interconnection standard exists that has national prominence for the North American power system and is well received by the international community.

Today, DOE-supported NREL is also providing leadership for the facilitation of SCC21 IEEE P2030 Draft Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), and End-Use Applications and Loads. This groundbreaking Smart Grid initiative was approved by the IEEE Standards Board in March 2009, and supports the National Institute of Standards and Technology's (NIST) role to coordinate the development of smart grid standards and the actual implementation of a critically needed standard through the EISA congressional mandate.

On track to be published in October 2011, the IEEE P2030 guide provides a knowledge base for understanding and defining Smart Grid interoperability of the electric power system with end-use applications and loads. IEEE P2030 provides a reference model and methodology to use to present interoperable interface design and implementation alternatives for systems that facilitate data exchange between Smart Grid elements, loads, and end-use applications. IEEE P2030 is also growing into a series of standards that share the common goal of Smart Grid interoperability supported by interrelated and complimentary technologies. This body of standards: P2030.1, P2030.2, P2030.3, etc., provide the guidance for implementation of the application interfaces identified throughout P2030.

The IEEE SCC21 2030 series of standards development projects that are currently underway are:

- P2030™, Draft Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), and End-Use Application and Loads (passed 2011);

- IEEE P2030.1™, Draft Guide for the Electric-Sourced Transportation Infrastructure;

- IEEE P2030.2™, Draft Guide for the Interoperability of Energy Storage Systems Integrated with Electric Power Infrastructure;

- IEEE P2030.3™, Draft Guide for the Testing of Energy Storage Systems Integrated with the Electric Power System.

With the growing application of power system integration (distributed generation, renewable electric systems, etc.) efforts are underway to address the high volume of power source penetration on the electric power system through the expansion of standards covering high penetration (IEEE Std 1547.8) and impact (IEEE Std 1547.7). Through testing procedures initiated by research and development, validation testing of the functionality of the IEEE P2030 interfaces is being planned at NREL. Protocols will be developed through the consensus process of the IEEE SCC21 2030 body of standards, as was done successfully in the development of 1547 and related standards. These standards efforts are a continuum of electric industry partnerships between NREL and DOE to ensure that the DOE OE mission of providing an integrated and modern electric power system is achieved.

References

1. IEEE P2030 Draft Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), and End-Use Applications and Loads, http://grouper.ieee.org/groups/scc21/dr_shared/2030/.
2. IEEE 1547 Series of Standards, http://grouper.ieee.org/groups/scc21/dr_shared/.
3. IEEE Standards Coordinating Committee 21, http://grouper.ieee.org/groups/scc21/index.html.
4. List of Detailed Descriptions for each IEEE Smart Grid Standard Published or in Development.

Mr. Richard (Dick) DeBlasio is Chief Engineer, National Renewable Energy Laboratory (NREL), and Chair of IEEE Standards Coordinating Committee on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage (SCC21). He is co-editor of the International Journal of Distributed Energy Resources. In 2010, he received the IEEE Charles Proteus Steinmetz Medal for contributions to the standardization and global impact of distributed electric power system technology. He is the 2011 recipient of the American National Standards Institute (ANSI) Finnegan Standards Medal for extraordinary leadership in the actual development and application of consensus standards. Mr. DeBlasio is a graduate of Santa Clara University and Temple University, completed the MIT nuclear reactor safety program; was a licensed research reactor operator, and served in the U.S. Air Force as a radar/electronics specialist from 1961 to 1965. He is an electrical engineer and a Life Senior Member of the IEEE and a member of the IEEE Standards Board and Board of Governors.

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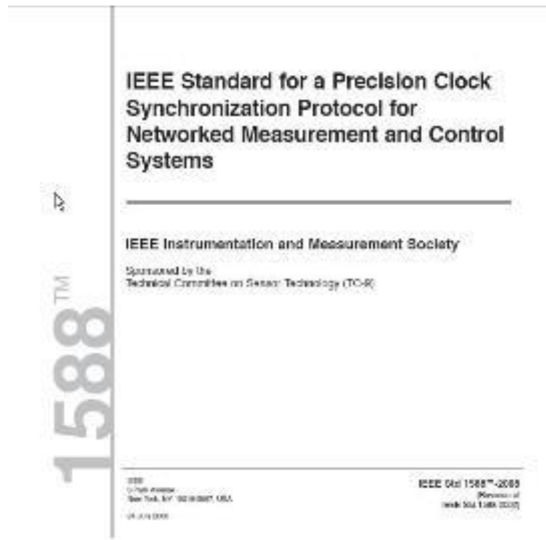
IEEE Standard 1588 Synchronization in Smart Grid to Ensure Performance, Reliability and Accuracy

By Lloyd Green

First Quarter 2012

Introduction



Smart Grids represents an opportunity to fundamentally improve the energy industry through optimization, reliability and efficiency. With the implementation of advanced technologies such as smart metering, distribution automation and smart appliances, the consumer monitors and controls energy usage. Keys to the smooth operation of the Smart Grid are performance and accuracy. Reliable synchronization techniques are essential in ensuring performance and accuracy criteria are met and maintained. Smart Grid encompasses a myriad of complex devices, which are required to seamlessly work with one another. The implementation of a conformity assessment program - such as the one offered by the IEEE Conformity Assessment Program (ICAP) – provides the assurance and confidence such devices have been validated to conform and interoperate.

Synchronization in the Smart Grid

Enabling the Smart Grid's ability to gather and process multitudes of data from intelligent electronic devices (IEDs) is a key operational aspect of the next-generation grid. Merging data from multiple sources, require accurate time-stamps. The network of substation end devices will require time synchronization with worst-case accuracy on the order of ±1 μs. Wide-Area Monitoring Systems (WAMS) can benefit from monitoring the accuracy of time synchronization and assessing the quality of the WAMS applications based on timing accuracy achieved. Similarly, substation monitoring and control applications, which propagate information to the wide area network (WAN), also need to have accurate time synchronization. In the event of a power outage, having accurate time synchronization helps to hone-in on the exact time and location a fault may have occurred, which may have taken extensive resources to troubleshoot in the past. The IEEE 1588-2008 - Precision Time Protocol (PTP) - provides a promising solution for the enablement of network time synchronization over the data line within a substation network.

Synchronized Phasor Measurement Units (PMUs) are measurements in AC quantities and are a key element of monitoring, protection, control and state estimation applications in power systems and are the basis for the implementation of WAMS. PMUs deliver precisely time synchronized (IEEE 1588-2008) values of voltage and current phasors and other power system related quantities like frequency, breaker positions etc. to a central data processing system, known as a Phase Data Concentrator (PDC). Each PDC collects the phasor measurement results of a certain area. Finally, the data of the entire power network are made available to a central management system called Super PDC. Due to the microsecond accuracy and the high sampling rates (10 to 60 per second) of the measurements, the system is able to capture and represent the dynamic behavior of the power network.

Synchronized phasor measurements are addressed in the following international standards: IEEE C37.118 and IEC 61850. These standards state; phasor angles must be measured relative to UTC with an accuracy of ± 26 μs.

Two IEEE standards working groups called IEEE-PSRC (for Power Systems Relaying Committee) and IEEE-SUB (for Substation Committee) is working on a PTP Profile for power systems. This is being done in close cooperation with another standards body namely IEC TC57. This profile is published as IEEE Standard PC37.238 and specifies a well-defined subset of IEEE 1588-2008 mechanisms and settings aimed at enabling device interoperability, robust response to network failures, and deterministic control of delivered time quality. It specifies the preferred physical layer (Ethernet), higher level protocol used for PTP message exchange and the PTP protocol configuration parameters. Special attention is given to ensuring consistent and reliable time distribution within substations, between substations, and across wide geographic areas.

Smart Grid Conformity Assessment and Certification

Smart Grid Conformity Assessment and Certification is necessary to establish consistency in the realm of Smart Grid appliances, and to give manufacturers an incentive for including these features in their appliances. Once a certification program is established, stakeholders can leverage their buying power to promote Smart Grid-enabled appliances, thus rapidly accelerating their development and acceptance in the market. The resultant benefits associated with a certification program include:

Assurance that product conforms to specifications;
Consensus-building among the Smart Grid community;
Reducing technology risk for utilities and consumers by ensuring interoperability;
Promoting competition through open standards.

Conformity assessment test suites are developed and implemented by test laboratories in a controlled environment. Test suites are designed to assess the performance of Smart Grid devices on the simulated or real network, where performance criteria, accuracy, reliability and interoperability are evaluated.

IEEE Conformity Assessment Program (ICAP)

The IEEE Conformity Assessment Program (ICAP) is a joint initiative of the IEEE Standards Association (IEEE-SA) and IEEE Industry Standards and Technologies Organization (IEEE-ISTO). ICAP has a goal of providing services that benefit the IEEE standards development community, as well as conformity assessment professionals responsible for evaluating new products against those standards. ICAP activities are designed to enhance the implementation and end user value for existing and developing IEEE standards. ICAP services will help bridge standards development activities with the conformity assessment activities that accelerate market acceptance and enablement of new products and technologies such as Smart Grids.

Lloyd Green is Marketing Director for the IEEE Conformity Assessment Program (ICAP). Previously, he was Director of Marketing and Customer Support at Brilliant Telecommunications. Brilliant developed highly accurate end-to-end timing and synchronization solutions, which addressed the Mobile Backhaul Picocell and Femtocell market. In 2011, Juniper Networks acquired Brilliant. At Juniper Networks, Lloyd assisted with the customer support and product integration efforts. Prior to Juniper Networks, Lloyd held technical, marketing and business development roles at Altamar Networks, Network Equipment Technologies (N.E.T) and British Telecom International (BTI). Lloyd holds at B.S. in Telecommunications from South East London Technical College.
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Better, Quicker Smart Grid and Vehicle-electrification Standards

By Jack Pokrzywa, Director of Global Ground Vehicle Standards with SAE International, and Mary Reidy, Chair of the IEEE P2030.1 Working Group

This article first appeared in the November 2011 issue of IEEE Smart Grid Newsletter.

A strategic partnership in vehicular technology related to the Smart Grid between the IEEE Standards Association (IEEE-SA) and SAE International is less than half a year old. But its value in influencing the speed and quality of global standards rollout is already in evidence. SAE International's work on a prototype charging coupler that leverages technology standardized by IEEE is one prime example.

In the first quarter of next year, SAE International plans to establish a standard, integrated coupler that would allow electric vehicles and plug-in hybrid electric vehicles (EVs/PHEVs) to be charged from either a conventional, 15-amp AC wall outlet or a DC connector of up to 90 kilowatts.

The SAE J1772™ "Electric Vehicle and Plug In Hybrid Electric Vehicle Conducive Charge Coupler" standard—agreed to in 2009 and officially published by SAE International in January 2010—is the world's first industry-consensus standard to provide critical guidelines for safety, charging control and connectors used to charge EVs/PHEVs. Automakers including Ford, General Motors, Honda, Nissan and Toyota have adopted SAE J1772™.

The in-development SAE J1772™ combo solution would take another leap toward stabilizing and unifying the global market for manufacturers of EVs/PHEVs. The standard is planned to enable both AC and DC Level 1 and faster, Level 2 charging all via a single vehicle inlet for the first time. Manufacturers would be able to leverage one coupler in EVs/PHEVs for all markets, regardless of the differences in electrical systems and charging locations from country to country. Integrating the different types of charging functionality would also greatly enhance the convenience of operating such a vehicle.

SAE J1772™ goes further still, by uniquely defining communications between an EV/PHEV and off-board charger and the Smart Grid. Power Line Communications (PLC) is defined in SAE J1772™ as the technology for enabling these vehicle-to-grid (V2G) communications, without requiring changes such as the addition of another pin to the coupler architecture.

That's where IEEE comes in. PLC implementations from both the HD-PLC Alliance and HomePlug® Powerline Alliance are based on IEEE 1901™-2010, the world's most mature, robust and advanced Broadband over Powerline (BPL) standard. And the IEEE 1901 Inter-System Protocol (ISP) prevents interference when the different PLC implementations are operated within close proximity of one another.

The drive toward an SAE J1772™ combo solution illustrates the need for the strategic partnership recently forged by the IEEE-SA and SAE International—and, more broadly, the coordination across historically disparate technology spaces and organizations that is demanded by the Smart Grid.

Another example is the ongoing IEEE P2030.1™ "Guide for Electric-Sourced Transportation Infrastructure" standards project. Work is being carried out by four task forces—vehicle technology (including charging systems), electric grid (from generation to consumer), roadmap (including privacy and roaming) and communication/cyber security—and then integrated within the full working group for broader discussion and input.

The Smart Grid effort is different in the sweep of technologies, industries and markets that it touches. For manufacturers, utilities, governments and consumers to realize the Smart Grid's benefits as quickly and cost-effectively as possible, the global standards community must operate cooperatively to logically integrate the work across technology spaces.

In the past, standards-development organizations (SDOs) tended to work chronologically—one after another, almost in a vacuum from one another. But, if an SDO missed a development in a related industry while working on its own standard for the Smart Grid, that SDO could be sending its stakeholders in the wrong direction—or in the right direction but much more slowly than is necessary. There are so many tentacles and the velocity of development is so great, that the Smart Grid demands a new, more coordinated mode.

The IEEE-SA/SAE International partnership in vehicular technology related to the Smart Grid—confirmed by a memorandum of understanding (MOU) signed in February 2011—is designed to accelerate more meaningful standards that drive greater improvements in market access, cost reductions and technological innovation. As part of the partnership, IEEE-SA and SAE International are sharing with one another their draft standards related to the Smart Grid and vehicle electrification.

Both SDOs are already global leaders in these domains.

SAE International Ground Vehicle Standards Technical Committees are leading the vehicle transportation industry in the development of standards to provide safer processes and practices for effective implementation of hybrid/electric vehicles. SAE International has developed 46 such standards; 30 more are in process. SAE J2836/1 "Use Cases for Communication Between Plug-in Vehicles and the Utility Grid," for example, establishes use cases, specifying the electronic information (such as vehicle/owner identity, charging-station location, the amount of electricity used and electricity price per time of day) that the vehicle will exchange with the grid.

IEEE, meanwhile, has more than 100 standards and standards in development relevant to the Smart Grid. In addition to IEEE P2030.1™, IEEE P2030™ "Draft Guide for Smart Grid

Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), and End-Use Applications and Loads and IEEE P1901.2™ "Standard for Low Frequency (less than 500 kHz) Narrow Band Power Line Communications for Smart Grid Applications" are among the active IEEE standards projects that figure to have strong bearing on the EV/PHEV industry.

By working to ensure that the two SDOs' efforts complement one another, IEEE-SA and SAE International are forging a more efficient and collaborative standards-development environment for their constituents. The SDOs' constituents are the driving force behind this partnership, in fact. They want a global marketplace with no boundaries, and IEEE and SAE International are global organizations that are known for producing globally relevant standards. This partnership is enabling IEEE and SAE International to do so more effectively and more quickly.

Jack Pokrzywa, is Director of SAE Ground Vehicle Standards, SAE International. He is responsible for the overall performance of the SAE Ground Vehicle Standards support system, including new business development, international standards harmonization, and liaison with other standards development organizations. In his responsibility for managing SAE Ground Vehicle Standards, he interacts regularly with trade associations, government agencies, national, regional and international standards developing organizations, and inspection authorities.
Prior to joining SAE, Pokrzywa was a Manager at the Automotive Industry Action Group, where he managed engineering projects for automotive OEMs and major suppliers. Before joining AIAG, Jack held several marketing management positions in Germany and the UK with Octal GmbH where he was responsible for initial start - up, daily operation and business development in Europe. He held various engineering positions with Lamb Technicon Corp. prior to that. An M.A. graduate of Warsaw's Catholic University, and Warsaw's Technical Institute with engineering certificate, Pokrzywa is a member of the Oakland County Workforce Development Board, ANSI International Policy Committee and ANSI/ISO Council.

Mary Reidy is a staff member of the National Grid's Smart Technology Center in Liverpool, New York, where she is responsible for identification of appropriate university-industry collaborations. She is Chair of the IEEE P2030.1 Working Group. A licensed professional engineer in New York State, Reidy has a doctoral degree and master's degree in business and engineering.

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Smart Grid Labs

First Quarter 2011

The Standards Education Committee (SEC) inquired about colleges and universities who have labs for teaching Smart Grid Technology. Below is a list of the responses received to date. If your university campus has a Smart Grid lab(s), please send us a description and we will add it to our list: ezine-eb@listserv.ieee.org.

Labs & Locations	**Description**	**Contact Person**
California State University at Long Beach, CA, USA	Have security lab for wireless sensors for Smart Metering in the Smart Grid and simulation labs for renewables and integration to Smart Grid.	Professor Tulin Mangir, Director, Nanotechnology Lab, Director, Wireless and Security Lab.
Chattanooga State	Have developed a Smart Grid lab around a new curriculum designed to prepare current and future power professionals.	Assistant Professor William Wan serves as the faculty lead for this initiative, as well the IEEE Student Chapter advisor.
Idaho State University, College of Technology, Pocatello, Idaho, USA	Teaching Smart Grid Technology in their Energy Systems Technology and Education Center as part of the Energy Systems Instrumentation and Control Engineering Technology AAS degree.	R. Scott Rasmussen, Interim Dean - College of Technology, Idaho State University College of Technology.
Mississippi State University, Mississippi State, MS, USA	Department of Electrical and Computer Engineering has an innovative smart grid demonstration laboratory used for both teaching and research.	Nicolas H. Younan, Ph.D., Professor & Department Head, James Worth Bagley Chair, Dept of Electrical & Computer Engineering, Mississippi State University.
Purdue University, College of Technology Facilities for Smart Grid & Power Electronics, West Lafayette, Indiana, USA	Smart Meter Integration Lab (SMIL) at the Department of Electrical and Computer Engineering Technology (ECET) at Purdue University, West Lafayette, IN, USA. Also, has another lab that develops hardware applications for Smart Grid.	N. Athula Kulatunga, Ph.D, Founder and Director of SMIL.

Portland State University	Developing power-related coursework and labs within the Electrical & Computer Engineering Department. One of the labs will focus on power systems protection, for which they will likely feature common and start-of-the art protection communications: Modbus RTU, TCP/IP, SONET, DNP3, IEC 61850, etc. The other lab will focus on power systems components, and they are considering implemention of an OPC-based networking mechanism that will allow them to aggregate the monitoring and control of various components of the power lab system, for which they will likely use IEC 61850 tagging standards for data handling.	Robert Bass, Ph.D., Associate Professor, Electrical & Computer Engineering
University of Arkansas at Fayatville, Fayetteville, AR, USA	Center serves as a working lab for both undergraduate and graduate work in high-power electronic systems technology. Center is available on a per-use fee basis to companies requiring high-current support for IEEE Std 1547 and UL1741 standard testing.	T. Avery Walton, Managing Director, National Center for Reliable Electric Power Transmission (NCREPT) and the NSF Center for Grid-Connected Advanced Power Electronic Systems (GRAPES)
University of Connecticut	Have simulation and hardware facilities for teaching about Smart Grid Technology.	Rajeev Bansal Professor & Head Dept. of Electrical & Computer Engineering, University of Connecticut

University of Kentucky, Lexington, KY, USA	Offer two smart grid classes, one is power technology focused offered by an ECD faculty, and one is computer network focused offered by a Computer Science faculty. Have software used for analyzing and simulating power systems and hardware for testing microprocessor based delays.	Yuan Liao, Associate Director for the Graduate Program of Power & Energy Institute of Kentucky, Associate Professor of Electrical & Computer Engineering, University of Kentucky.
University of Texas Panamerican, Edinburg, Texas, USA	Have a facility called UTPA Smart Micro Grid. It is located within the Electric Circuits Lab; voltage is 3-phase 208 V. They have 3 smart meters which are connected by IEEE 488 boards to a PC running on Lab VIEW.	Jaime Ramos, Ph.D., P.E. Assistant Professor, Electrical Engineering The University of Texas Panamerican Edinburg, TX
Virginia Tech, Blacksburg, Virginia, USA	Have a Wide Area Measurement, Protection, and Control laboratory, which is an integral part of the Smart Grid. The Power System Laboratory at Virginia Tech is a teaching and research facility available to graduate students and senior undergraduate students in power engineering. The birth place of the phasor measurement unit, PMU, has been a smart grid lab since 1986 when the development of the first PMU started as a research project for the department of energy. At present the lab is used for graduate research and senior design projects on wide area measurement, adaptive protection, and a control of the power grid.	Dr. Virgilio Centeno is the primary contact for the lab.

Washington State University	Smart Grid Demonstrations and Research Investigation Lab (SGDRIL). Research Goals: Develop, Test and Validate Smart Grid Algorithms as well as Test Smart Grid Devices.	Anurag K Srivastava Assistant Professor Director, School of Electrical Engineering and Computer Science, Washington State University, Pullman, Washington USA

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IEEE Standards and Smart Grid

[Visit the IEEE's Smart Grid website for the latest developments in smart grid standards.]

IEEE Smart Grid Newsletter

Follow the IEEE Smart Grid Standards Development Activities

The IEEE SCC21, established by the IEEE Standards Association (IEEE-SA), sponsors standards projects, develops, IEEE draft standards, and conducts coordination activities among individual IEEE Societies. Visit: IEEE SCC21 Standards Coordinating Committee on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage

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More Resources

Press release from SA on new smart grid standard IEEE 1591.3™-2011, Standard for Qualifying Hardware for Helically-Applied Fiber Optic Cable Systems (WRAP Cable)
http://standards.ieee.org/news/swire/index.html?hq_e=el&hq_m=2667302&hq_l=24&hq_v=38b94075ac - std1

Repository of Articles & Publications on IEEE's Smart Grid Standards

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Scholarship Opportunities

IEEE PES SCHOLARSHIP PLUS AWARD RECIPIENTS ANNOUNCED: The IEEE Power & Energy Society is pleased to announce the inaugural IEEE PES Scholarship Plus Initiative™ award recipients. Ninety-Three (93) IEEE PES Scholarship recipients have been selected from 51 U.S. universities for the 2011-12 Academic year. These scholarships are being distributed through the IEEE Power & Energy Scholarship Fund which is being used to support the IEEE PES Scholarship Plus Initiative.

These undergraduate students were selected by industry and academic representatives based primarily upon: academic preparation; extra-curricular activities and leadership; interest in engineering in general, and power and energy engineering in particular; and overall assessment of student's potential for a successful power and energy engineering career. Visit the IEEE PES Scholarship Plus Initiative web site for more information.

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Publications & Articles on Smart Grid Standards

Publication include the following:

[1] R. DeBlasio, "IEEE Guide for Smart grid Interoperability of Energy Technology and Information technology Operation with the Electric Power System (EPS), End-Use Applications, and Loads", Published by IEEE on September 10, 2011.

[2] "Future of the Electric Grid: An Interdisciplinary MIT Study," 2011. http://web.mit.edu/mitei/research/studies/documents/electric-grid-2011/Electric_Grid_Full_Report.pdf

[3] R. DeBlasio, "All Together Now: Cross-discipline Collaboration, IEEE P2030 and the Smart Grid," IEEE Smart Grid Magazine, June 2011.

[4] R. DeBlasio, "Connecting the Dots on Smart Grid," Published in Energy Collective, March 23, 2011.

[5] R. DeBlasio, "Renewables-Interconnection Standards for the Smart Grid", Consulting-Specifying Engineer magazine, August 2011.

[6] R. DeBlasio, "Sharing Lessons Learned in the Global Smart Grid Movement," The Energy Collective magazine, May 2011.

[7] R. DeBlasio, "Smart Grid Update: Standards Development and Renewable Energy", North American Clean Energy magazine, February 2011.

[8] B. Kroposki and T. Basso, "Microgrids: Ready for Business," Electricity Today," October 2011.

[9] R.DeBlasio, T. Basso, "Advancing Smart Grid Interoperability and Implementing NIST's Interoperability Roadmap", Conference Paper, NREL/CP-550-47000, Presented at the grid-Interop 2010 Conference, in Denver Colorado.

[10] R. DeBlasio and C. Adams, " Unifying the Smart Grid", published in Pure Power Magazine.

[11] R. DeBlasio and T. Basso, "Enabling Smart Grid Interoperability: A "Systems of Systems" Approach via IEEE P2030 and IEEE 1541, Connectivity Week, Santa Clara California.

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Detailed Descriptions of each IEEE Smart Grid Standard Published or in Development

By Richard (Dick) DeBlasio

First Quarter 2012

IEEE 1547™ Series:

[IEEE Std 1547™-2003, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems]

The IEEE Std 1547™-2003 is the first in the 1547 series of planned interconnection standards and provides interconnection technical specifications and requirements as well as interconnection test specifications and requirements. The IEEE Std 1547 stated requirements are universally needed for interconnection of distributed resources that include both distributed generators as well as energy storage systems, including synchronous machines, induction machines, or power inverters/converters and will be sufficient for most installations. Traditionally, utility electric power systems (EPS—grid or utility grid) were not designed to accommodate active generation and storage at the distribution level. As a result, there were major issues and obstacles to an orderly transition to using and integrating distributed power resources with the grid. The lack of uniform national interconnection standards and tests for interconnection operation and certification, as well as the lack of uniform national building, electrical, and safety codes, were understood.

In February 2003, Std 1547 was affirmed by the ballot group of 230 members. In June 2003, IEEE Std 1547 was approved by the IEEE Standards Board and in October 2003 approved as an American National Standard. In the Energy Policy Act of 2005, IEEE 1547 standards were required to be considered for interconnection of distributed resources to the grid. In 2008, the IEEE Std 1547 was reaffirmed by 181 balloters. Reaffirmation is consensus proclamation that the standard, as currently written, is not obsolete and does not contain erroneous information.

[IEEE Std 1547.1™-2005, IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems]

The IEEE Std 1547.1™-2005 provides the test procedures for verifying conformance to IEEE Std 1547-2003. IEEE Std 1547.1 provides conformance test procedures to establish and verify compliance with the requirements of IEEE Std 1547. When applied, the IEEE Std 1547.1 test procedures provides a means for manufacturers, utilities, or independent testing agencies to confirm the suitability of any given interconnection system or component intended for use in the interconnection of DR with the electric power system (EPS). Such certification can lead to the ready acceptance of confirmed equipment as suitable for use in the intended service by the parties concerned.

IEEE Std 1547.2™-2008, IEEE Application Guide for IEEE Std 1547(TM), IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems

The IEEE Std 1547.2™-2008 provides technical background and application details to support understanding of IEEE Std 1547. The guide facilitates the use of IEEE Std 1547 by characterizing various forms of distributed resource technologies and their associated interconnection issues. It provides background and rationale of the technical requirements of IEEE Std 1547. It also provides tips, techniques, and rules of thumb, and it addresses topics related to distributed resource project implementation to enhance the user's understanding of how IEEE Std 1547 may relate to those topics.

IEEE Std 1547.3™-2007, IEEE Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems

IEEE Std 1547.3™-2007 is intended to facilitate interoperability of DR interconnected with an area EPS. IEEE Std 1547.3 is intended to help stakeholders in distributed resource installations, implement optional approaches for monitoring, information exchange, and control to support the operation of their distributed resources and transactions among the stakeholders associated with the distributed resources. IEEE Std 1547.3 describes functionality, parameters, and methodologies for monitoring, information exchange, and control related to distributed resources interconnected with an area electric power system. The focus is on monitoring, information exchange, and control data exchanges between distributed resource controllers and stakeholder entities with direct communication interactions. This guide incorporates information modeling and use case approaches, but it is also compatible with historical approaches to establishing and satisfying monitoring, information exchange, and control needs for distributed resources interconnected with an area electric power system.

IEEE Std 1547.4™-2011, IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems

The IEEE Std 1547.4™ draft guide covers intentional islands in EPSs that contain distributed resources (DR). The term “DR island systems,” sometimes interchanged with micro-grids, is used for these intentional islands. DR island systems are EPSs that: (1) have DR and load, (2) have the ability to disconnect from and parallel with the area EPS, (3) include the local EPS and may include portions of the area EPS, and (4) are intentionally planned. DR island systems can be either local EPS islands or area EPS islands. The IEEE Std 1547.4 document addresses issues associated with DR island systems on both local and area islanded EPSs. It provides an introduction and overview and addresses engineering concerns related to DR island systems. The document provides alternative approaches and good practices for the design, operation, and integration of DR island systems with EPS. This includes the ability to separate from and reconnect to part of the area EPS while providing power to the islanded EPSs. This guide includes the distributed resources, interconnection systems, and participating electric power systems.

IEEE Std P1547.5™

IEEE Std P1547.5™ draft document provides guidelines regarding the technical requirements, including design, construction, commissioning acceptance testing, and, maintenance performance requirements, for interconnecting dispatchable electric power sources with a capacity of more than 10 MVA to a bulk power transmission grid. The purpose of the IEEE Std P1547.5 project is to provide technical information and guidance to all parties involved in the interconnection of dispatchable electric power sources to a transmission grid about the various considerations needed to be evaluated for establishing acceptable parameters such that the interconnection is technically correct. It should be noted that since the P1547.5 project was initiated, the North American Electric Reliability Corporation (NERC) has been established as the electricity reliability organization that may establish standards for generation systems providing wholesale electric services on the transmission grid.

IEEE Std P1547.6™-2011, IEEE Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks

The IEEE Std P1547.6™ draft recommended practice builds upon IEEE Standard 1547 for the interconnection of distributed resources to distribution secondary network systems. It establishes recommended criteria, requirements and tests, and provides guidance for interconnection of distribution secondary network system types of area EPS with distributed resources providing electric power generation in local electric power systems (local EPS). The IEEE Std P1547.6 document focuses on the technical issues associated with the interconnection of area EPS distribution secondary networks with a local EPS having distributed resources generation. The recommended practice provides recommendations relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. In this IEEE Std P1547.6 document, consideration is given to the needs of the local EPS to be able to provide enhanced service to the DR owner loads as well as to other loads served by the network. Equally, the standard addresses the technical concerns and issues of the area EPS. Further, this standard identifies communication and control recommendations and provides guidance on considerations that will have to be addressed for such DR interconnections.

IEEE Std P1547.7™

The IEEE Std P1547.7™ draft guide describes criteria, scope, and extent for engineering studies of the impact on area electric power systems of a distributed resource or aggregate distributed resource interconnected to an area electric power distribution system. With the creation of IEEE Std 1547, that had led to the increased interconnection of distributed resources throughout distribution systems. This IEEE Std P1547.7 document describes a methodology for performing engineering studies of the potential impact of a distributed resource interconnected to an area electric power distribution system. The impacts study scope and extent are described as functions of identifiable characteristics of the distributed resource, the area electric power system, and the interconnection. Criteria are described for determining the necessity of impact mitigation. The establishment of this IEEE Std

P1547.7 guide allows distributed resource owners, interconnection contractors, area electric distribution power system owners and operators, and regulatory bodies to have a described methodology for when distribution system impact studies are appropriate, what data is required, how they are performed, and how the study results are evaluated. In the absence of such guidelines, the necessity and extent of DR interconnection impact studies has been widely and inconsistently defined and applied. The IEEE Std P1547.7 project was initiated in January 2009.

IEEE Std P1547.8™

The IEEE P1547.8™ is a draft recommended practice for establishing expanded use of IEEE Std 1547. The need for P1547.8 is to address industry driven recommendations and NIST Smart Grid standards framework recommendations (e.g., NIST priority action plans). The P1547.8 example considerations include: low voltage ride thru; volt-ampere reactive support; grid support; two-way communications and control; advanced/interactive grid-DR operations; high-penetration/multiple interconnections; interactive inverters; energy storage; electric vehicles; etc.

IEEE 2030™ Series:

IEEE Std 2030™-2011, IEEE Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), End-Use Applications, and Loads

The IEEE 2030 project provides guidelines in understanding and defining smart grid interoperability of the electric power system with end-use applications and loads. Integration of energy technology and information and communications technology is necessary to achieve seamless operation for electric generation, delivery, and end-use benefits to permit two-way power flow, with communication and control. Interconnection and intra-facing frameworks and strategies with design definitions are addressed in the IEEE 2030 document, providing guidance in expanding the current knowledge base. This expanded knowledge base is needed as a key element in grid architectural designs and operation to promote a more reliable and flexible electric power system. The IEEE 2030 standards development inaugural meeting was held in June 2009 with capacity in-person registration of 150 individuals and close to 200 others registered to participate via webinar. The IEEE 2030 development was on a fast-track schedule targeting approval and publication in September 2011, which was accomplished.

IEEE Std P2030.1™

The IEEE P2030.1 is a draft guide focusing on electric-sourced, road-based personal and mass transportation. The guide provides methods for many different stakeholders, such as utilities, end-users, and infrastructure providers to develop the support systems necessary for wide-scale implementation of electric-sourced vehicles. Additionally, the guide describes end-to-end system based energy efficiency methods for electric-sourced vehicles.

IEEE Std P2030.2™

The IEEE Std P2030.2 is a draft guide focusing on the interoperability of discrete and hybrid energy storage systems and the EPS. The guide is intended to assist in the understanding and characterization of energy storage and systems and how these systems may be used compatibly with the EPS. Additionally, the guide provides a knowledgebase for terminology, test procedures, operation, and the application of engineering principles related to discrete and hybrid energy storage systems and the EPS.

IEEE Std P2030.3™

The IEEE P2030.3 is a draft guide addressing Test Procedures for Electric Energy Storage Equipment and Systems for Electric Power Systems Applications . The standard establishes test procedures for electric energy storage equipment and systems for electric power systems (EPS) applications. Additionally, requirements on installation evaluation and periodic tests are included in this standard.

Mr. Richard (Dick) DeBlasio is Chief Engineer, National Renewable Energy Laboratory (NREL), and Chair of IEEE Standards Coordinating Committee on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage (SCC21). He is co-editor of the International Journal of Distributed Energy Resources. In 2010, he received the IEEE Charles Proteus Steinmetz Medal for contributions to the standardization and global impact of distributed electric power system technology. He is the 2011 recipient of the American National Standards Institute (ANSI) Finnegan Standards Medal for extraordinary leadership in the actual development and application of consensus standards. Mr. DeBlasio is a graduate of Santa Clara University and Temple University, completed the MIT nuclear reactor safety program; was a licensed research reactor operator, and served in the U.S. Air Force as a radar/electronics specialist from 1961 to 1965. He is an electrical engineer and a Life Senior Member of the IEEE and a member of the IEEE Standards Board and Board of Governors.

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Smart Grid Videos & Online Courses

The Smart Grid involves the use of communications and computing technology to transmit and distribute energy more efficiently. This video describes the smart grid and how it will reduce our carbon footprint through energy efficiency and the integration of renewable sources of energy.

Featuring interviews recorded at the IEEE Plug-In Hybrid Vehicles: Accelerating Innovation Conference (2007) and the IEEE Energy 2030 Conference (2008). Produced by IEEE and ScienCentral, Inc., with funding from IEEE Power & Energy Society, IEEE-USA, and the IEEE New Technology Directions Committee (NTDC).

Video will launch in You Tube (8:54).

IEEE Standards for Power & Energy video provides a quick overview of important current power and energy standards and their uses.

Video will launch in You Tube (4:18).

What are the relevance of standards to Smart Grid. Interview with Chuck Adams, Past-President of the IEEE Standards Association. Includes Chinese translation.

Video will launch in You Tube (5:06).

Ning Hua, IEEE's Director of Business Development, China, talks about how the IEEE Standards Association is involved in the Smart Grid. (Language is in Manderin).

Video will launch in You Tube (2:17).

IEEE's eLearning Library now has 10 online courses (fee-based) in the area of Power, Energy and Industry Applications.

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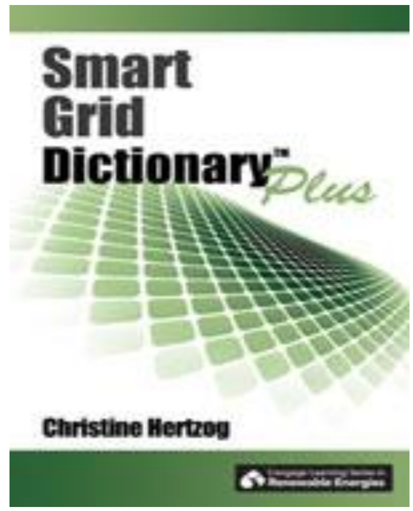
Book Review

By Amin Karim
Director of Academic Outreach at DeVry University.

Smart Grid Dictionary Plus



Compiled by Christine Hertzog and published by Delmar Cengage Learning.

Do you know the difference between GPR, GPRS and GPS? Open page 105 of the Smart Grid Dictionary Plus and you will find that these similar-sounding acronyms are not only unrelated, but also they are from very different engineering fields. So why are they on the same page?

As you'd expect, Smart Grid Dictionary Plus is an alphabetized list of words. This collection of words spans terminology, concepts, acronyms and jargons – just to name a few aspects pertaining to Smart Grid industry. It includes – and importantly, describes – everyday vocabulary used by engineers and professionals employed by electric utilities, regulatory agencies, metering and automation application industry, and standards organizations.

Besides the explanation of various terms, the Smart Grid Dictionary Plus includes a broad collection of Smart Grid standards. It lists 11 International Electrotechnical Commission (IEC) standards, 54 Institute of Electrical and Electronics Engineers (IEEE) standards and 2 International Organization for Standardization (ISO) standards. In addition, the dictionary references many US and international organizations and consortia that are active and influential in Smart Grid ecosystem.

The Smart Grid is increasingly becoming an integral part of our homes and offices. As a consumer I want to know the difference between a Smart Appliance and a Smart Meter; as an engineer I want to know whether my products are compliant to IEEE 2030; as a home owner I want to know if my home is Solar-Ready and Storage-Ready; and I want to know whether my house is on a MicroGrid or a PicoGrid! Step one – understand what these terms mean.

In my opinion, this is an excellent reference book for an engineer's desk.

Smart Grid Dictionary Plus is compiled by Christine Hertzog and published by Delmar Cengage Learning. For further information, visit www.cengage.com.

Opinions expressed in this article are the opinions of the author and not those of their employers or of IEEE.

Amin Karim is the Director of Academic Outreach at DeVry University. Prior to this position, he served as the national dean of the college of technology for approximately eight years. Before joining DeVry in 1991, he served as an electrical engineer in the power and manufacturing industry and as a faculty and a department head of engineering technology program. He is a past Chair of the Electronics and Computer Engineering Technology Department Heads Association of the American Society for Engineering Education and served as a TAC of ABET evaluator for engineering technology programs. Currently, he is serving as the vice-chair of the Standards Education Committee for IEEE.

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Participate in our Smart Grid Survey

The IEEE Standards in Education Committee is researching the need for education and training needs to support the growing interest and activity associated with implementing the power Smart Grid program. This program is well explained on the NIST, US Department of Energy and IEEE Standards Association web sites.

We are interested in what is presently available and what may be needed in the future, including the application and generation of applicable standards on the operation and the interoperability of components of the Smart Grid system.

Please take a moment to answer these short questions if you are at all interested in Smart Grid activity and even consumer impact

Go to the Smart Grid Education & Training Survey.

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IEEE Standards Education Committee Student Application Paper Grants

by David Law

Knowledge of industry standards helps facilitate the transition from classroom to workplace by aligning educational concepts with real-world applications and market constraints. IEEE encourages the introduction and use of technical standards in the classroom.

In support of the IEEE Standards Education Committee's (SEC) mission, in particular to actively promote the integration of standards into academic programs, the IEEE SEC is offering grants to both students (500 USD) and faculty mentors (300 USD) to promote the use of industry standards in projects.

These grants are offered to students in all stages of their study (e.g., undergraduate, post graduate, doctoral) and for all types of projects (e.g., design, development, research). The grant requires submission of a paper on completion of the project describing the design choices driven by, and the application of, industry standards in meeting the project goal. This provides the applicant(s) the additional opportunity of having a paper published by the IEEE.

The application process is reasonably lightweight and so far the success rate of application has been high, with the main reason for rejection being meeting the requirement to use industry standards in projects. The key to a successful application is to have a project that is based on the investigation or application of industry standards.

Simply using components that conform to a particular standard, for example using an IEEE 802.11™ WiFi Router to communicate a WiFi connected laptop as part of the project, is not sufficient. What we wish to see is a paper that highlights specific design choices in the project driven by an understanding, and application, of the industry standard(s) used.

To learn more and to apply for a grant visit http://standardseducation.org/applications/. Also, don't miss our FAQ section in this eZine, which is quite helpful.

The SEC reviews each final paper carefully and the accepted final papers are published to our Student Application Papers website. Please take some time to read through the successful papers for some inspiration.

We are also publishing "Best of Student Application Papers" in each issue of the Standards Education eZine. Two appear in this issue related to our Smart Grid theme. The first is from students at Indiana University-Purdue University Fort Wayne entitled "A Wireless Energy

Custodian Network." The second paper is called "Smart House with Power Line Communication Network," written by students at Simon Fraser University.

David Law is a Distinguished Engineer at Hewlett-Packard Networking and has worked on the specification and development of Ethernet products since 1989. Throughout that time he has been a member of the IEEE 802.3 Ethernet Working Group where he has held a number of leadership positions. He served as the Vice-Chair of IEEE 802.3 from 1996 to 2008 and in 2008 was elected to Chair of IEEE 802.3. David has been a member of the IEEE-SA Standards Board since 2005, has served as the Chair of IEEE-SA Standards Board Review Committee (RevCom) since 2008, and is currently serving as the Chair of the IEEE Standards Education Committee. In 2000 he received the IEEE-SA Standards Medallion for 'leadership and technical contributions to Ethernet networking standards' and in 2009 he received the IEEE Standards Association Standards Board Distinguished Service award 'For long term service to improve the operation and integrity of IEEE-SA governance'. David has a BEng (hons) in Electrical and Electronic Engineering from Strathclyde University, Glasgow, Scotland.

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IEEE Standards in Power Engineering Education

By Dr. Liuqing Yang
Colorado State University

First Quarter 2012

In the fall semester of 2011, I taught a graduate course on Signal Processing for Power System. Throughout the semester, it has become more and more clear that this subject cannot be taught without involving IEEE standards.

As power system is the biggest and most complicated system developed in the past century, it inherently requires cooperability across vast geological and regional operation facilities. Standardization hence becomes a necessity. Power system development has a long history and lots of field experiences have been gathered in the standardization process. With the new horizon of revolutionizing our current power system into smart grid, drastically increased measurements and processing are inevitable. However, the only way for signal processing researchers and engineers to stay practical is to work with existing standards, as well as towards new standards.

Among students' course projects, several turned out to be heavily related to a variety of IEEE standards. One of them is directly relevant to IEEE Standard C37.118™-2005 on "IEEE Standard for Synchrophasors for Power Systems." This project attempts to improve the frequency estimation of synchrophasors based on the discrete Fourier transform (DFT) of the time-domain voltage or current samples. This is very pertinent to the requirements for synchrophasors to operate under off-nominal system frequencies, which will occur more often in the envisioned smart grid than the traditional power system due to the increasing inclusion of distributed renewable power sources with higher volatility, the more and more popular electrical vehicles, and possible islanding operations.

The unprecedented amounts of measurements and communications are also prone to faulty measurements and communication errors. Another project deals with the processing of synchrophasor data at the measurement data concentrator. Therein, advanced signal processing techniques such as compressive sensing are introduced to handle bad synchrophasor measurements in power system state estimation in order to meet the accuracy requirement specified in IEEE Std. C37.118-2005.

The third project is about the feasibility and security issues of the IEEE 802.15.4™ wireless communication standard in the automatic metering infrastructure (AMI) for the smart grid. A supplement using in-network aggregation with homomorphic encryption is investigated to protect customer privacy associated with high-frequency metering data.

Dr. Liuqing Yang received her Ph.D. degree in Electrical and Computer Engineering from the University of Minnesota, Minneapolis, in 2004. Since August 2004, she has been with the Department of Electrical and Computer Engineering at the University of Florida, Gainesville, where she became an Associate Professor in 2009. She joined Colorado State University as an Associate Professor in 2010. Her general interests are in areas signal processing with applications to communications, networking and power systems – subjects on which she has published more than 140 journal and conference papers, 2 book chapters and 1 book. Dr. Yang was the recipient of the Best Dissertation Award in the Physical Sciences & Engineering from the University of Minnesota in 2004, the Best Paper Award at the IEEE International Conference on UWB in 2006, the AFOSR Summer Faculty Fellowship in 2007, the ONR Young Investigator Program (YIP) award in 2007, the NSF Faculty Early Career Development (CAREER) award in 2009, and the IEEE GLOBECOM 2010 Outstanding Service Award. She is serving as an active reviewer for more than 10 journals, as TPC chair/member for a number of conferences, and as an associate editor for IEEE Transactions on Communications, IEEE Transactions on Wireless Communications, IEEE Transactions on Intelligent Transportation Systems, and PHYCOM: Physical Communication.

Students at Colorado State University working on the above mentioned projects, were successful recipients of IEEE Student Project Grants available for projects using industry standards. Visit the FAQ section of this eZine and the IEEE Student Application Paper website to learn more about applying.

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Best of Student Application Papers

In each issue we will publish selected examples of final application papers from students who received IEEE grants to help with projects that include technical standards.

The following paper is an example of a successful project with good applications and a well-written final report.

A Wireless Energy Custodian Network

Team Members: Nusaybah Abu-Mulaweh, Renee Chandler, Edwin Chobot, Daniel Newby
Indiana University - Purdue University Fort Wayne, Department of Engineering
Faculty Advisor: Chao Chen, Ph.D.

This document defines the determined qualities required for the IPFW Senior Design Project: A Wireless Energy Custodian Network. The main goal of this project was to design, build, and test a wireless sensor and actuator network for monitoring the energy usage of AC devices in a home environment. Each node in the network reads the energy usage of an AC device connected to it and wirelessly reports the readings to a central server. The server displays the readings from these nodes through a user interface on a computer in real-time, in such a manner that users can understand their electricity usage patterns and adapt their behavior to reduce energy consumption. Moreover, users are able to remotely control the power On/Off of individual devices via the central server.

1. System Overview

In a world of rising energy costs and dwindling natural resources capable of producing energy, people and businesses are starting to look for better ways to help reduce their increasing electric bills. One way of reducing these costs is to monitor how much power is being consumed in real time and from that data make informed decisions about how to manage the electrical devices being powered. A system which can give users an idea of how much power is being, has been, and might be consumed will allow them to adjust their habits and lower the costs.
Our project was to design a wireless energy custodian network that will monitor the power usage of alternating current devices/appliances in a home environment. The system consists of two or more “node” modules and a Central Server Module. The nodes record

data about the power consumption of the devices/appliances that are connected, and wirelessly transmit that data to the central server for processing. The server displays the readings from these nodes through a user interface in real-time. The goal of this project is to help users better understand how power is consumed by their devices and adapt their behavior to reduce their energy consumption.

Most electronic devices, even if turned off, will continue to draw power from a standard electrical outlet unless the device is manually unplugged. This power is called "standby power." Although individual electronic products may not draw enough power while in standby power to be noticed, the average American family has almost forty devices constantly consuming power. The standby power consumption of these devices accounts for almost 10% of household electricity use. Because of this, our design integrates an actuator into each measurement node that will automatically turn on and off the power supply to the AC devices remotely.

The remote on/off control can also be used in other manners to further reduce energy. For example, the air conditioner can be turned on and off remotely based on the inputs from temperature sensor readings and energy usage; the lights can be turned on and off remotely based on the inputs from motion sensor readings and energy usage; the water heater can be turned off before midnight and turned on before sunrise. The design of these appropriate control mechanisms, however, depends on the specific devices and the habits of individual users.

Therefore, in our project, we specifically target the standby power to illustrate the feasibility and functionality of the on/off control. Furthermore, this on/off control enhances the wireless network from monitoring only to also including the actuator part, which extends the capability of the whole system and makes our design different from other products on the market.

Figure 1 shows an application of this wireless energy monitoring system in a home scenario, where the measurement nodes are connected to major home appliances in different rooms, and the central server module displays the energy consumption of these appliances on a computer screen.

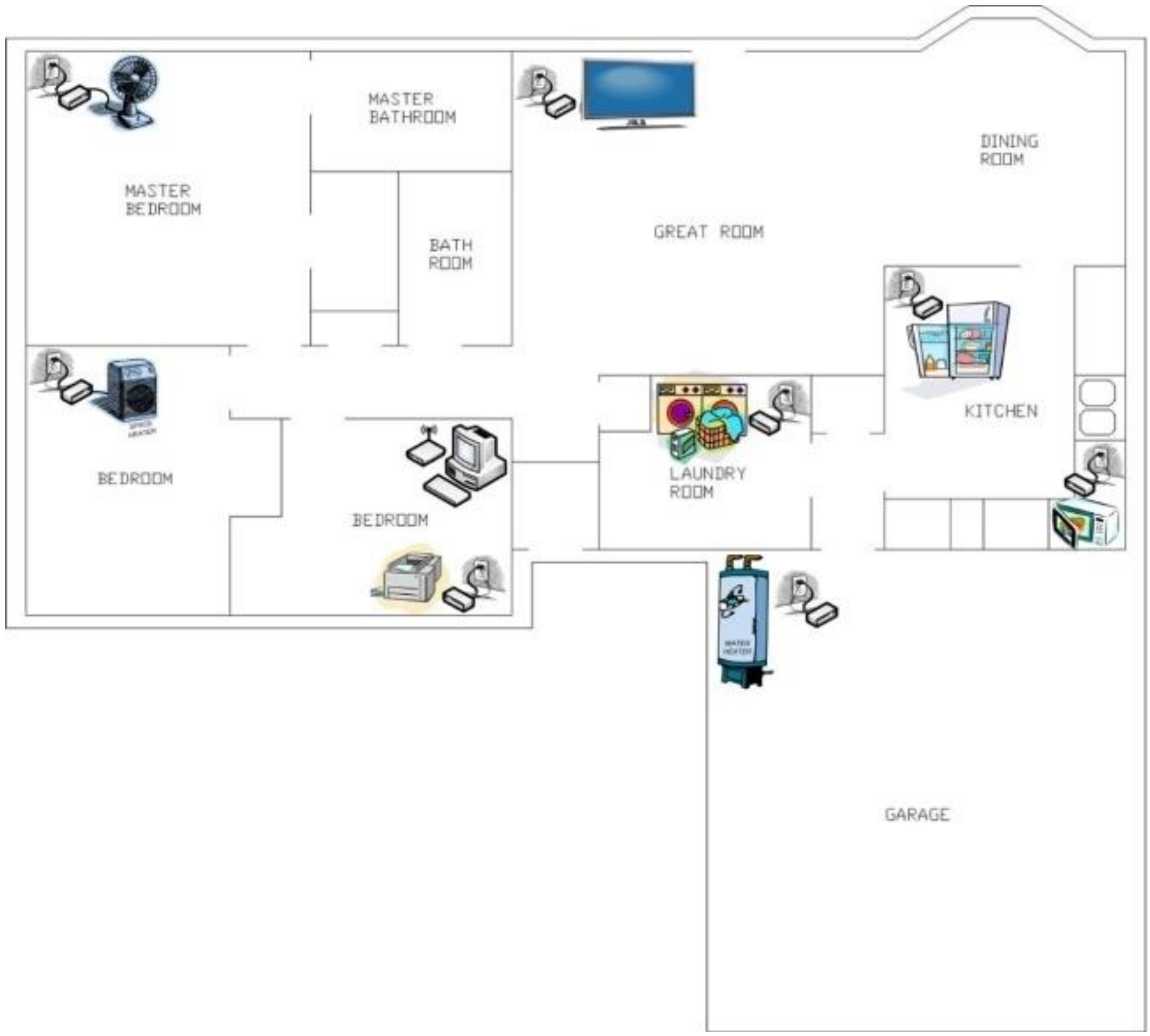

Figure 1: A wireless energy monitoring system at home

Our group decided to design and implement a system prototype with two measurement nodes and one central server module, where the nodes communicate directly to the server and the server displays the measurement results through the computer. Requirements of the system prototype include:

- The nodes monitor and wirelessly transmit the energy usage of connected AC devices.
- The central server module displays the energy reading in real-time through a graphical user interface while updating once every minute.
- The central server module is able to turn on and off the individual nodes. The on/off control will be tested in the application of standby power reduction.
- The system prototype will be deployed and tested indoors, in a typical home environment in the United States. The communication distance from the measurement nodes to the central server module is within 50 feet.

Some products already on the market which function in a similar manner as the system we designed are the TED 1000 Series and Kill-A-Watt. The TED 1000 series takes the readings from an electrical panel in a home and tracks energy usage of an entire household and can display this information on a computer using the included software [1]. Kill-A-Watt is a device which monitors the amount of energy consumption of a connected appliance by the kilowathour and displays it on an LCD display [2]. Our design is capable of monitoring and controlling multiple devices while neither the TED 1000 Series nor Kill-A-Watt can control the appliance.

2. Selection of a Wireless Standard

Our system is targeted for indoor use at a typical American home; therefore a short-distance wireless communication system is more appropriate. Two types of wireless communication standards are suitable for this application: IEEE 802.15.1 (Bluetooth) [3] for medium rate wireless personal area networks (WPAN) and IEEE 802.15.4 (ZigBee) [4] for low rate WPANs.

IEEE 802.15.1 is adapted from Bluetooth, which specifies short-range RF-based connectivity for portable devices. Bluetooth is designed for small and low cost devices with low power consumption. Since Bluetooth is geared towards handling voice, images, and file transfer, it has a data transfer rate on the order of 1Mbps with a relatively complex protocol. The operational range for Bluetooth is only around 10 meters. With amplifier antennas its range can be boosted to 100 meters, but with higher power consumption.
The IEEE 802.15.4 standard specifies the physical layer and medium access control used for the low-data-rate, short-range transmissions that are also well suited for this application and environment. Transfer rates from 20 kbps to 250 kbps will provide sufficient throughput for the amount of data to be wirelessly transmitted. A typical single-family structure will be enclosed within the 100-meter transmission range specified. Additionally, the star network used in our design is one of the two supported network topologies. The central server in our project operates as the PAN coordinator, controlling the two-way communications between the server and each node. Finally, IEEE 802.15.4 standard will allow for expansion to our network as more devices are added to the energy monitoring net.

3. Project Design

Our system prototype has two measurement nodes and a central server module. Each measurement node is plugged into a standard NEMA 15-5 electrical outlet. An AC device is then plugged into the node for power measurement. Each measurement node contains the components necessary to measure the power consumption, wirelessly transmit the information to the central server module, and control the power on/off of the connected device. In order to measure the power consumption, a voltage divider network and low impedance current sense resistor are connected to an energy metering chip. The energy metering chip samples the voltage and current signals, calculates the power consumption, and outputs a pulsed digital signal with a frequency related to the power consumption. The microcontroller then samples the pulsed digital signal from the energy metering chip and

converts to a power value. The microcontroller also has the capability of controlling the power delivered to the connected device with a solid-state relay.
Several indicator LEDs identify the node's current mode of operation, and a reset button allows the user to restore power to a device that is currently off. The block diagram of the node's components is shown below in Figure 2.

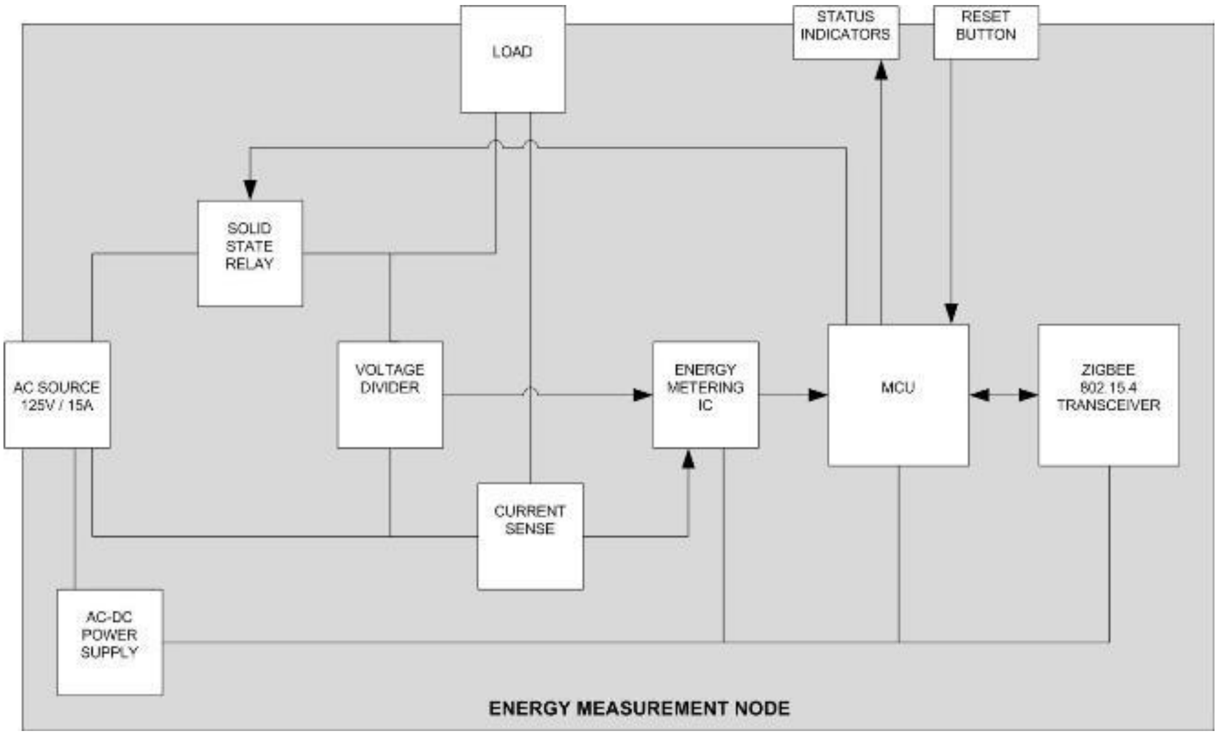

Figure 2: The block diagram of a measurement node

The central server module (CSM) receives the power measurements from each of the nodes and then forwards the measurements to the computer for display. The measurement data is received through a ZigBee transceiver and passed directly to the computer program through the USB port.

The power on/off signals from the computer program are passed to the ZigBee transceiver through the USB port. The components in the central server module are powered through the USB port as well. Figure 3 shows a block diagram of the main components included in the central server module. We used the XBee Explorer Dongle unit [5] from the SparkFun Electronics. This unit has a USB UART interface IC device (FT232RL) that interfaces between the XBee transceiver [6] and the USB port. It is also equipped with a USB port and a dock for the XBee transceiver. The XBee Explorer Dongle cost $24.95 and the XBee transceiver cost $19.00.

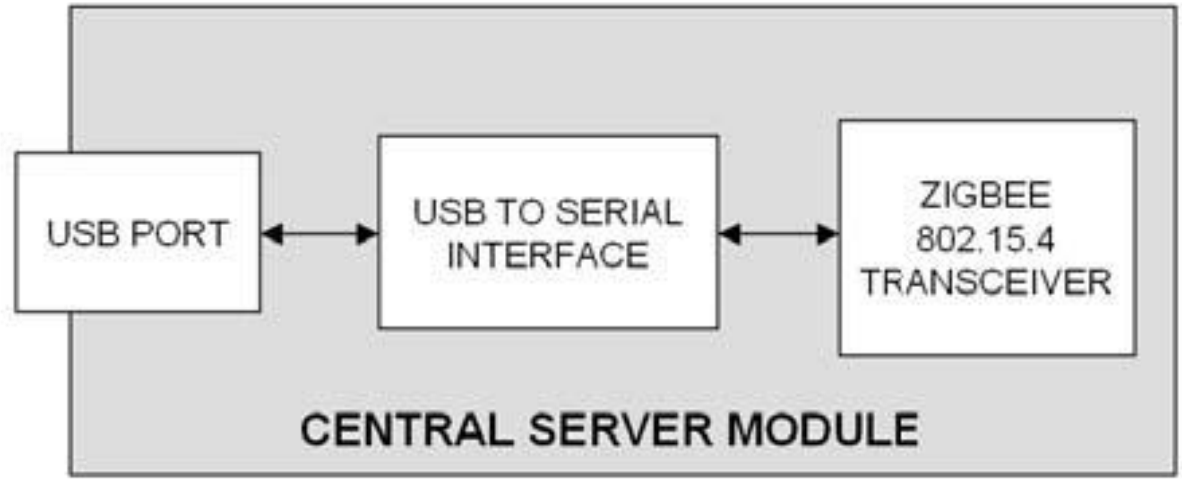

Figure 3: The block diagram of the central server module

3.1 Measurement Node Hardware

The overall size of the measurement node prototype is 4.7" x 4.7" x 2.4" and the total cost for each measurement node was $112.79. Figure 4 below shows the assembled node with the main components specified.

Figure 4: Photograph of the completed measurement node

3.2 Measurement Node Software

The node software was written and tested using the Keil uVision4 embedded development tool for the 8051 microcontroller [7]. The ANSI C programming language was used to write our code, which was then compiled into a HEX file to program the microcontroller. The main functions of this software include collecting measurements from the energy-metering IC chip, transmitting the measurements to the CSM, receiving control signals from the CSM, and controlling the power supplied to the connected appliance.

3.3 Graphical User Interface (GUI) Software

The GUI software was written for a Windows based personal computer and tested using the Microsoft Visual Studio development suite. The main purpose of the GUI software is to display the power consumption data in real time and control the solid-state relay for each of the nodes.

To achieve these goals, the software is organized into two threads: the transmission thread and the user input thread. The transmission thread will execute once per minute, as that is the rate at which the nodes transmit their data. The transmission thread consists of the reading the wirelessly transmitted data, adding a timestamp, checking the standby power requirements, saving the power measurements to a file, and then updating the graphical display with the latest power measurement. The user input thread allows the software to asynchronously handle input from the user each time the user presses a button on the GUI.

Figure 5: Screenshot of GUI displaying the power consumption for two nodes

Figure 5 above shows the testing of a space heater with only the fan on (no heat) and an LCD computer monitor. Each of these two devices are plugged into a node and their power consumption are reported to and displayed at the GUI software. The GUI software also has the capability to calculate the total energy used over a specified period. The user can provide a "start date" and "end date" for the software to calculate the total energy consumed by both nodes. To calculate the energy, the software reads in historical data from the CSV file and multiplies the time duration values by the power usage value. These are summed up and converted from Joules to kilowatt-hours and then displayed to the user. Figure 6 below shows the window displaying the energy consumption for a user-specified time period.

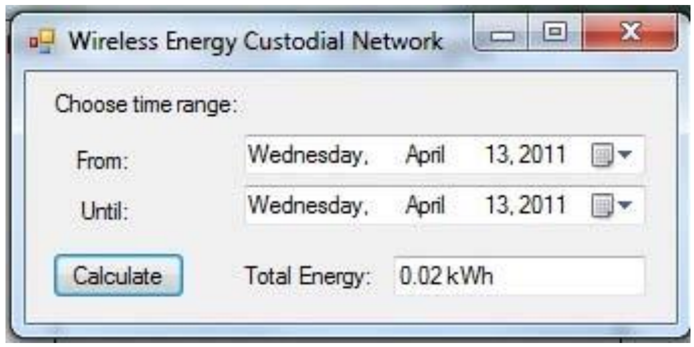

Figure 6: Calculating energy consumption over a time period

An additional power save feature is included in the GUI software. The purpose behind the power-save feature is to reduce power consumption by devices that go into a "standby" mode. The design and the testing of this power-save feature will be described in detail in Section 4.2.

4. Testing and Evaluation

For our design we tested each of the main components required for proper operation of the nodes and the central server module. This included measuring the power consumption at the node, wirelessly transmitting the information to the CSM, rendering the information on the GUI in real time, and transmitting a control signal back to the node if necessary. For the measurement nodes, the individual components tested included the AC-DC power supply, the solid state relay, the optocoupler, the energy metering IC chip, the IEEE 802.15.4 transceiver. For the CSM, the components tested included an additional IEEE 802.15.4 transceiver and the GUI software. The power supply, solid-state relay, optocoupler, and energy metering IC chip performed as expected during testing and are not discussed in detail here. The wireless transceiver performance and the GUI software evaluation are discussed in further detail below.

4.1 Wireless Signal Testing

Two types of testing were conducted: range testing and impediment testing. Range testing was testing how far the node and CSM could be placed relative to each other while still receiving a signal which was free of transmission errors. Impediment testing was testing in which the node or the CSM was placed in or around objects which could cause distortion or loss of signal (for example, metallic objects like stoves, refrigerators, etc.) The design requirement was for a range of 50 feet to allow for use inside of a standard home.

The nodes and the CSM were taken to a large three story home with a walk-out basement in Fort Wayne, Indiana. The results of the range testing were as follows in Tables 1-3. For the purposes of this test the result of "Strong" is defined as no noticeable transmission problems while "Weak" is defined transmission reception was sporadic or not at all.

Table 1: Lateral range testing (single floor)

Range (feet)	Impediments	Signal
5	None	Strong
10	None, Interior Brick Wall	Strong
15	None, Interior Brick Wall	Strong
20	None, Interior Brick Wall	Strong
25	None, Interior Brick Wall, Interior Wall	Strong
30	None, Interior Brick Wall, Interior Wall	Strong
35	None, Interior Brick Wall, Interior Wall	Strong
40	None, Interior Walls	Strong
45	None, Interior Walls	Weak

Table 2: Vertical range testing (multiple floors)

Node Floor	CSM Floor	Signal
Upstairs	Ground	Strong
Basement	Ground	Strong
Upstairs	Basement	Strong

Table 3: Impediment testing

Node Level	CSM Level	Comment	Signal
Basement	Ground	Node Inside Washing Machine	Strong
Ground	Ground	Node Inside Oven	Strong
Ground	Ground	Refrigerator Between CSM and Node	Strong

Our testing concluded that the range requirement was satisfied and that no noticeable impairment to the signal occurred when transmitting near or in large metallic objects.

4.2 Standby Power-Save Feature Testing

When the standby power-save feature for a specified node is enabled, the device that is connected to that node is first put to standby mode, and the GUI software gathers the next

10 readings it receives for that node and averages them. The average is multiplied by 120% and set as the threshold for that node. Then the device is set to normal working condition. Once the device has operated for 30 consecutive minutes (i.e., 30 consecutive readings) below the threshold, the GUI software then determines that the device is working under the standby mode and shuts off power to the device via the wireless control signal. Any reading above the threshold resets the count of "below threshold" values.

In order to test the standby power-save feature, we monitored a computer while it was consuming standby power. We first enabled the power-save feature for the computer node, then waited for the 10 samples to be calculated in the threshold calculation phase. After the standby threshold was calculated, we turned on the computer to show usage above the threshold, which should not shut power off to the device. Then, we put the computer back into standby mode, which consumed less than the threshold. After 5 consecutive samples under the threshold were received, power was automatically shut off to the computer. Here we used 5 consecutive samples instead of 30 for the purpose of reducing the testing time and showing a live demo. Figure 7 below shows the GUI after the standby power-save feature was enabled for the computer. As indicated by Figure 7, the computer still consumes around 20 W (about 27% to 33% of its power in normal working condition of 60-75 W) while in standby mode. The GUI software was able to remotely turn off its power automatically after the computer has been in standby mode for a while. Therefore, our designed system is able to help users reduce their energy consumption by reducing the standby power consumption. Once the power of the device is cut off by the CSM, a user can restore the solid-state relay by pressing a push-button at the node, so that the device can be turned on again locally.

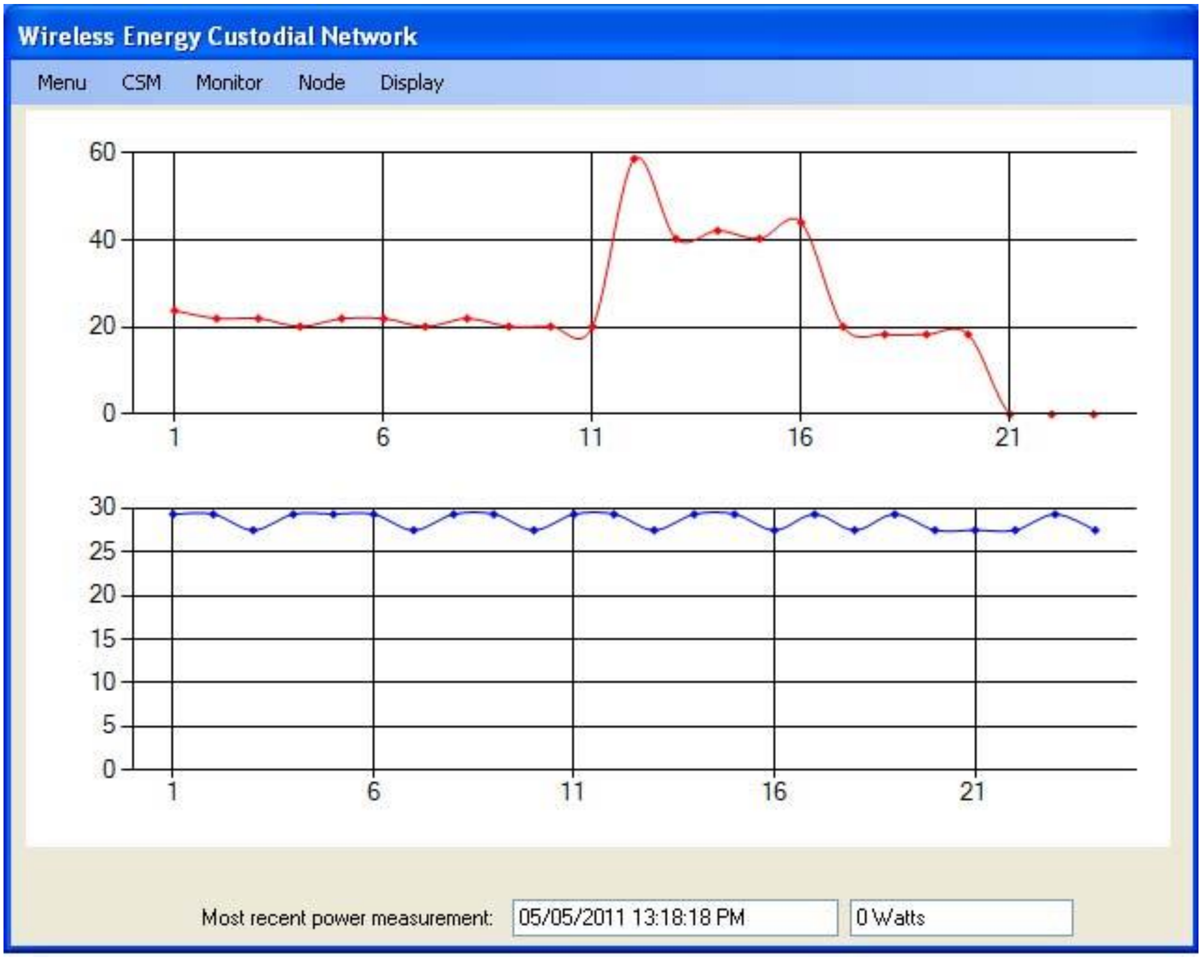

Figure 7: Screenshot of GUI after the computer (top graph) has reached its auto-shutoff point

5. Conclusion

This paper describes a capstone senior design project that builds a wireless sensor and actuator network for monitoring the energy usage of AC appliances in a home environment. The design of the system prototype including two measurement nodes and a central server module is explained. The system prototype meets the design criteria. Additionally, the implementation and performance analysis of this design project have been completed. The XBee transceiver module selected for this project has a low maximum transmit power of 1mW (0dBm) and a high receiver sensitivity of -92dBm. This resulted in a maximum transmission range of 40 feet between the nodes and the CSM. In the future, a transceiver with a larger transmit power could be tested to improve the network range. Finally, IEEE 802.15.4 standard will allow for expansion to our network as more devices are added to the energy monitoring network.

References

1. TED 1000 | In-home Electricity Monitor. <http://www.theenergydetective.com/store/ted-1000>, accessed in May 2011.

2. P3 - Kill A Watt, <http://www.p3international.com/products/special/P4400/P4400-CE.html>, accessed in May 2011.

3. IEEE 802.15 WPAN Task Group 1 (TG1). <http://www.ieee802.org/15/pub/TG1.html>, accessed in May 2011.

4. IEEE 802.15 WPAN Task Group 4 (TG4). <http://www.ieee802.org/15/pub/TG4.html>, accessed in May 2011.

5. XBee Explorer Dongle - SparkFun Electronics, <http://www.sparkfun.com/products/9819>, accessed in May 2011.

6. Digi International Inc. "XBee® & XBee-PRO® ZB ZigBee® PRO RF Modules," <http://www.digi.com/products/wireless/zigbee-mesh/xbee-zb-module.jsp>, accessed in May 2011.

7. Silicon Labs, "C8051F35x Analog-Intensive MCUs," <http://www.silabs.com/products/mcu/mixed-signalmcu/Pages/C8051F35x.aspx>, accessed in May 2011.

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Best of Student Application Papers

In each issue we will publish selected examples of final application papers from students who received IEEE grants to help with projects that include technical standards.

The following paper is an example of a successful project with good applications and a well-written final report.

Smart House with Power Line Communication Network

Project Team: Kia Filsoof, Pranil Reddy, Yalda Hakki, Kevan Thompson, Michael Kubanski

School of Engineering Science, Simon Fraser University, Burnaby, BC, Canada

Supervisors: Dr. Andrew Rawicz and Mr. Steve Whitmore

Executive Summary

In this day and age, communication is a very integral part of our society, and we rely more and more on it with new advances in technology every year. The Internet is a very popular medium for communication of ideas and information between people, but also for communication between devices, allowing for control of a device remotely. It is limited though as not everything can be hooked up directly to the Internet in a feasible and cost effective manner, for example, home appliances.

Control over home appliances, and more generally, control over a home or any other building remotely, has the potential to ease most peoples' hectic lives. Instead of having to physically get home and put on dinner after a long day of work, the alternative would be to connect to your home online, set the oven temperature and turn it on given that dinner was prepared ahead of time. What if you left for a vacation and forgot to turn off the lights? The ability to check on your house online would be very convenient.

1. Introduction

With the addition of the Prometheus to your house, you now have the ability to control your appliances from anywhere in the world using the Internet. With Just a click of a mouse, you are now able to switch your house lights you forgot to turn off when leaving the house.

The objective of our project is to establish a working control system which will use power line communication to communicate and control home appliances. This project in particular, is aimed to be used within a house to control appliances such as light bulbs, coffee makers, and toasters. The major advantage of our product from similar devices on the market is that we are aiming to add extensive security to the already existing power modulation communication protocol. Moreover, many existing products have non-intuitive user interface, causing the user experience to be rather unpleasant. With the design of Prometheus, we are aiming to provide simple and innovative user interaction with the product.

After extensive research, power line communication has been successfully chosen as the method of communication for this control system for number of reasons. One of the major advantages with power line communication is that it utilizes the existing structure's electrical grid for communication purposes. This feature allows the overall cost of the system to drop by a noticeable amount.

Other options which were available to us for implementing the Prometheus device were to use either wireless or Ethernet for means of communication. As for the wireless method, even though it does not require any wiring, it would still add unnecessary complexity to the design of the system, causing the price to increase. Similarly, as for the Ethernet method, the cost would increase due to the cabling required.

2. Proposed Design Solution

Our proposed solution is to create a network of microcontrollers which will communicate over a Power Line Communication Network (PLCN). This solution will have a high performance microcontroller which will act as a master, to a series of low powered device microcontrollers. The master microcontroller will communicate to the device microcontrollers over a PLCN. This network will save costs by combining the power and communication lines into a single entity. In addition, it also consists of a very friendly user interface.

The user will select devices to be activated or deactivated by a password protected website which they will be able to access from any computer connected to the internet. This website will be stored on the master microcontroller, which will act as a web server. When a user has finished selecting devices the master microcontroller will then send the data to the appropriate device microcontroller which will then turn on or off the device.

For this project we attempt to control several simple devices such as lamps, or a coffee machine. If more time and funding were available, we would attempt to control more complex devices such as a smart oven, which would have configurable temperatures, and timing.

3. System Overview

The Prometheus general block diagram in Figure 1 shows the basic functionality of our product. The user can easily control a desired device remotely in the building from the Internet. The building master controller determines what device the user intends to control by the data received and sends control signals to the Power Line Communication Modem

(PLCM). The control signals are processed by the PLCM and sent through the electrical grid. These signals are then recovered from the electrical grid by a PLCM located in the room and passed on to the corresponding device controller to control the required device.

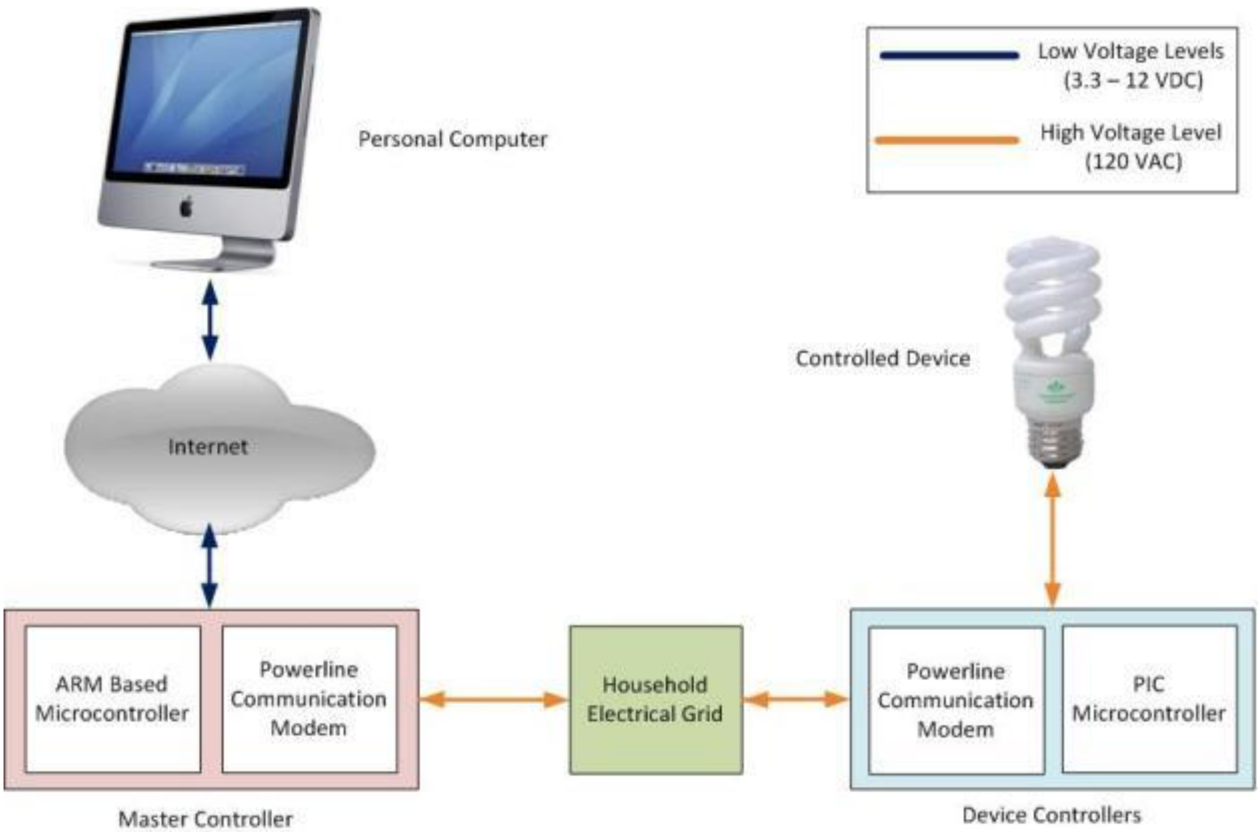


Figure 1: Conceptual Overview

3.1 Master Controller

The purpose of the master controller is to provide an interface between the user and the Prometheus system, as well as provide overall control of the system.

The mater controller, illustrated in Figure 2, consists of a TS-7200 Single Board Computer (SBC) purchased from Technologic Systems.

Figure 2: TS-7200 SBC

The processor on the TS-7200 SBC is an ARM 9 processor which operates at 200MHz, and has 32MB of high speed DDR RAM. Debian Linux V2.6 is installed on a 2GB compact flash card, and is loaded on boot-up by manually interrupting the Redboot boot loader program. The user web interface will be provided by an Apache web server included in the Linux operating system. A terminal interface is provided by the COM1 serial port, and the COM2 serial port will be used for communication between the master controller and the device controller.

3.2 Power Line Communication Modem (PLCM)

The PLCM is responsible for transmitting/receiving the data signals over the power line. There will be a master PLCM which will be used by the master controller to communicate with the devices over the power line. There will also be an additional PLCM per each device's device controller which will be connected to the power line communication network.

The PLCM consists of four stages to account for data communication over the power line: modulator circuit, coupling circuit, decoupling/signal conditioning circuit, and demodulation circuit [1]. On the transmitting side, the RS232 data signal from the microcontroller is fed through the modulator circuit which will modulate this RS232 data into its corresponding FSK format. Then, the FSK modulated data signal is fed through the coupling circuit to be superimposed onto the AC power line signal. On the receiving side, the FSK modulated signal is extracted from the power line through the decoupling circuitry, and demodulated back into its RS232 data format via the demodulator circuit.

3.3 Device Controller

The device controller is required to communicate with the master controller and in regards to controlling the corresponding device connected to it. The device controller needs to be cheap, power efficient, and capable of handling communications with the master controller and controlling the required device. The device controller will need to receive and transmit RS232 data through the PLCMs and control a device using external circuitry connected to its I/O ports. The most cost efficient choice that can handle the processing requirements and the one we have chosen is a PIC microcontroller.

4. Use of IEEE Standards

IEEE Std 643™-2004 (Revision of IEEE Std 643-1980): Guide for Power-Line Carrier Applications [2]

We made use of this standard to aid us towards achieving data transmission over power line communication networks. This standard is provided with many useful guidelines regarding component selection, frequency selection, noise considerations, and channel losses which were very useful in regards to completion of our project.

IEEE Std 2001-2002: Software Engineering — Recommended Practice for the Internet — Web Site Engineering, Web Site Management, and Web Site Life Cycle [3]
We used this IEEE standard to follow industry related practises in design of our system's internet user web page.

5. Current State of the Project

The Prometheus system can currently control home or business electrical devices through a power line communications network on the building's power grid. A user can log onto a website hosted by the master controller, which will send control signals through the power grid to the corresponding device controller. The master controller and device controllers each consist of one power line communication modem (PLCM) which allows for their transmitting and receving of data over the power grid.

Currently the Master Controller uses a TS-7200 SBC with a Debian Linux operating system. The master controller can use an Apache webserver to create a dynamic CGI webpage that can communicate with a static process which runs the network. This static process, called master_controller, sends and recieves data from the CGI program and also controls the device controller network. Currently this network is only configured to operate with a maximum of two device controllers. Each device controller must connect to the network, and will then recieve data as the user uses the website. In order to communicate with the device controllers, the master controller uses an RS-232 interface in cominbation with GPIO. The GPIO is needed to turn on or off the transmitter on the PLCM.

As of to date, the PLCM is meeting majority of its most critical proof-of-concept requirements. The PLCM is capable of sending and receiving digital data reperesented in RS232 format over the power line at any desired baud rate. It can be connected to any microcontroller device and grant it communication over the power line. In other words, it is not dependent on any specific required microcontroller. The PLCM's interface to the power line consists of a high frequency coupling transformer with two filtering capacitors sitting on the hot and neutral lines of the power line. The purpose of these capacitors in conjunction with the transformer is to prevent the 60-Hz AC power signal from getting through to the low voltage secondary side of the PLCM. There are also two 250 mA fast blow fuses sitting onwards these capacitors to provide protection of our circuitry from any current surges on the power line.

When transmitting, the PLCM takes the RS232 control signals from a microcontroller, modulates them into their corresponding FSK format, and passes them on to an H-bridge circuitry which drives the coupling transformer with the required amount of current. Conversely, when receiving, the PLCM extracts the FSK formatted control signals from the coupling transformer, passes them on to a band-pass filter which will further filter out the 60-Hz power signal and the high frequency noise signals. After filtering is done, the control signals are passed on to a pulse-shaping circuitry and then a phase-locked loop which will demodulate the FSK signals into their corresponding RS232 format and output them to the receiving input of the microcontroller.

The device controller consists of a PIC mircocontroller connected to the PLCM through an RS232 line driver/reciever and an external device control circuitry used to control devices connected to 120 VAC power line. The device controller communicates with the master controller via RS232 packets which are passed to and from the PLCM and controls devices based on the control packets it recieves. The PIC drives an output pin high to turn a device on, and holds it low when the device is off. When the pin is driven high, it powers the optoisolator's LED, which drives the other side of isolator. This in turn provides just enough base current to switch a NPN power transistor on and switch a 12 VDC relay on. This closes the device circuit and allows the 120 VAC source to power the device.

6. Conclusion

In less than 4 months, through close collaboration between team members, we were able to carry out extensive research and design to develop a functional prototype incorporating the majority of functional specifications promised in a timely manner. Our product is currently capable of controlling the on/off state of any electrical equipment within a building from over the internet. Data communication over the power line has been successfully achieved, and consists of minimal error. The microcontrollers installed within our system provide extensive communication protocol within the system to account for any possible errors and addition or removal of any devices.
One of the critical improvements which can be made to our system towards having it ready for market would be to compactly enclose all current three units into one for every module. This enclosure will allow for more safety, easier installation and portability of our system by the user. The intended final enclosure is to be made of metal to allow for making use of grounding and heat dissipation purposes.

Another improvement to our overall system would be to reduce the overall power consumption of our system, leading to a less costly and more efficient device. All three of the master microcontroller, device controller, and the PLCM include circuitry which can be optimized more towards increasing the system's efficiency.

Lastly, our final product will need to be capable of controlling more complex devices. Currently, our system can only control the on/off state of the corresponding electrical devices. As for future improvements, we are aiming to interact further with the internal circuitry of more complex devices. For example, we could use our system to control the overall operation of an electrical oven such as controlling its temperature, the corresponding heating pads, its internal clock, and timer.

7. References

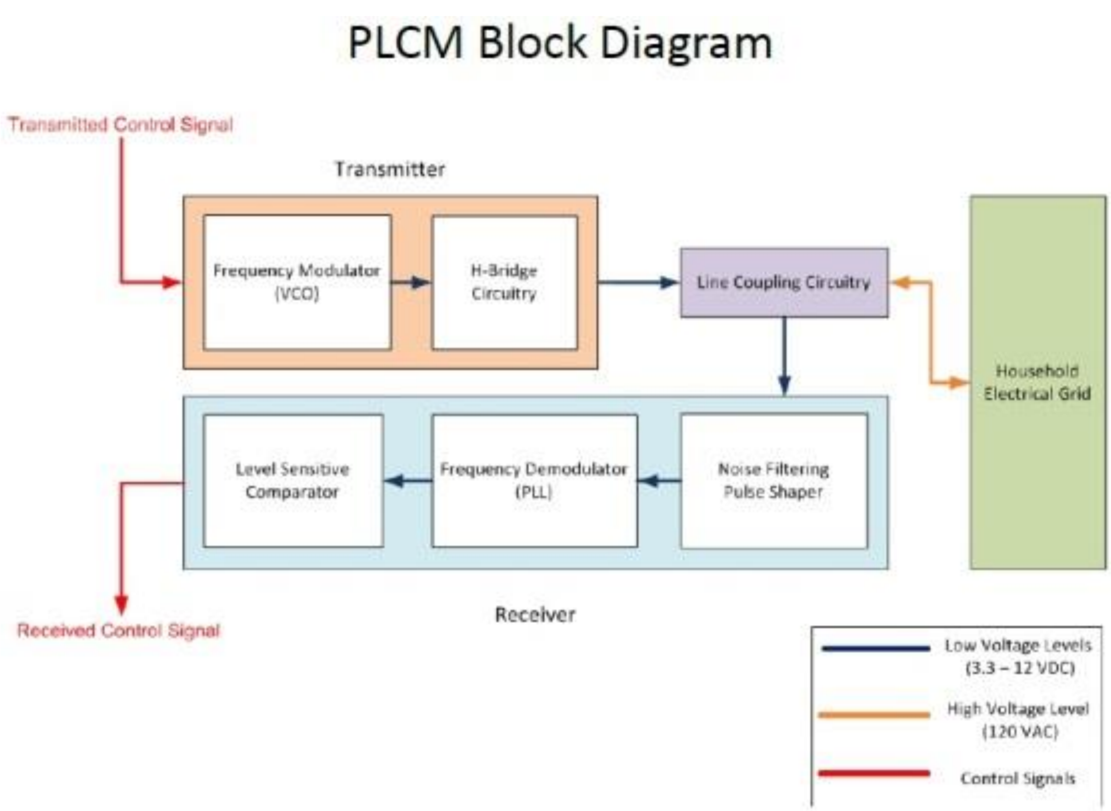
[1] R. E. Redgate, A. R. Carson, M. T. Collins, K. Q. Lam, D. P. Ketron and D. L. Toland, "Information and Control Communication over Power Lines," US 6281784 B1, 08/28, 2001. Available: http://www.freepatentsonline.com/6281784.pdf. [Accessed: May 5, 2010].

[2] IEEE Power Engineering Society, "IEEE Std 643™-2004 (Revision of IEEE Std 643-1980): Guide for Power-Line Carrier Applications."

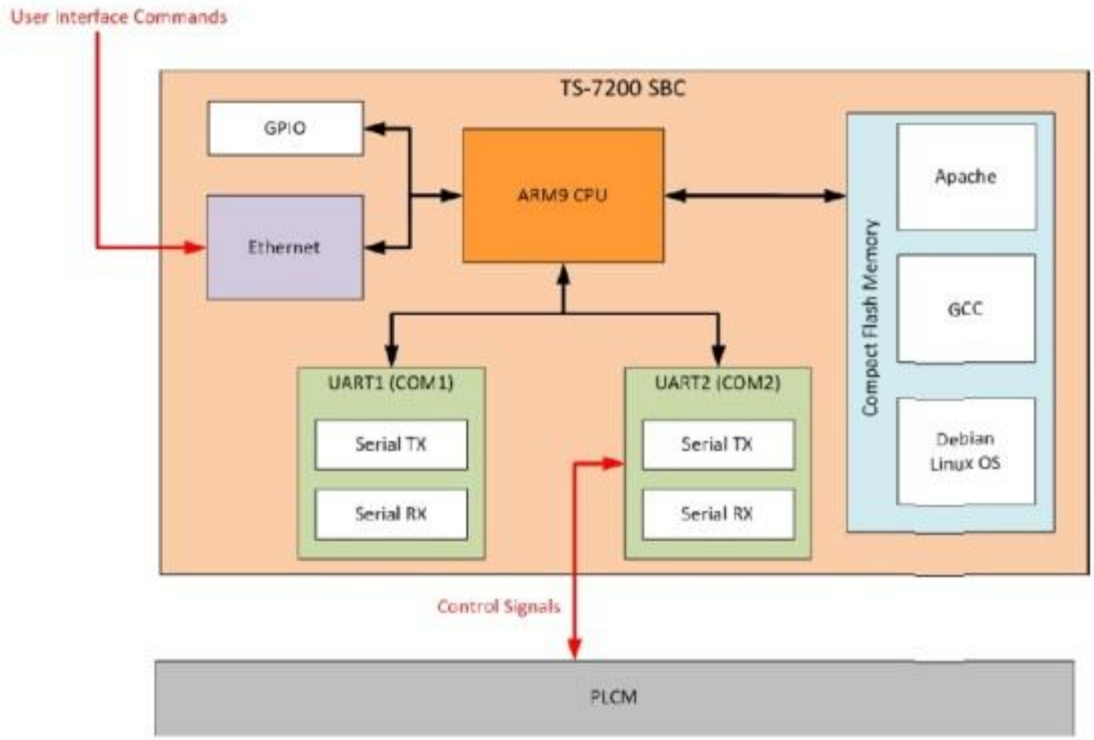
[3] IEEE Computer Society, "IEEE Std 2001™-2002: Software Engineering--Recommended Practice for the Internet--Web Site Engineering, Web Site Management, and Web Site Life Cycle."

8. Appendix

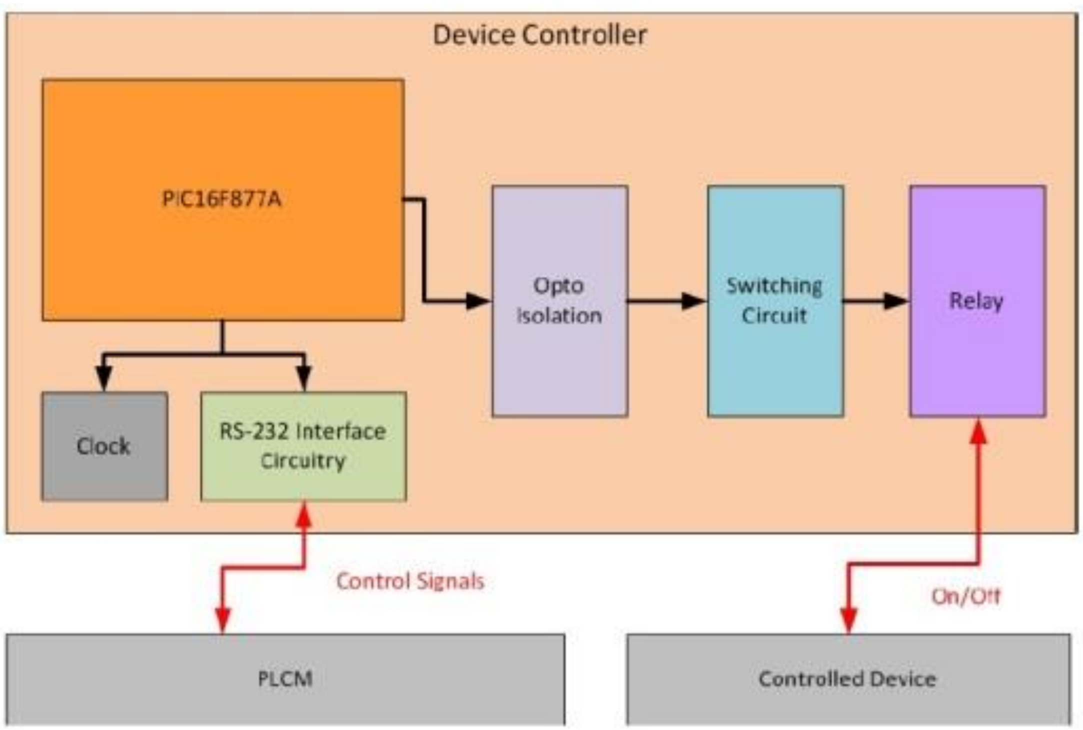
8.1 Power Line Communication Modem's (PLCM) Block Diagram



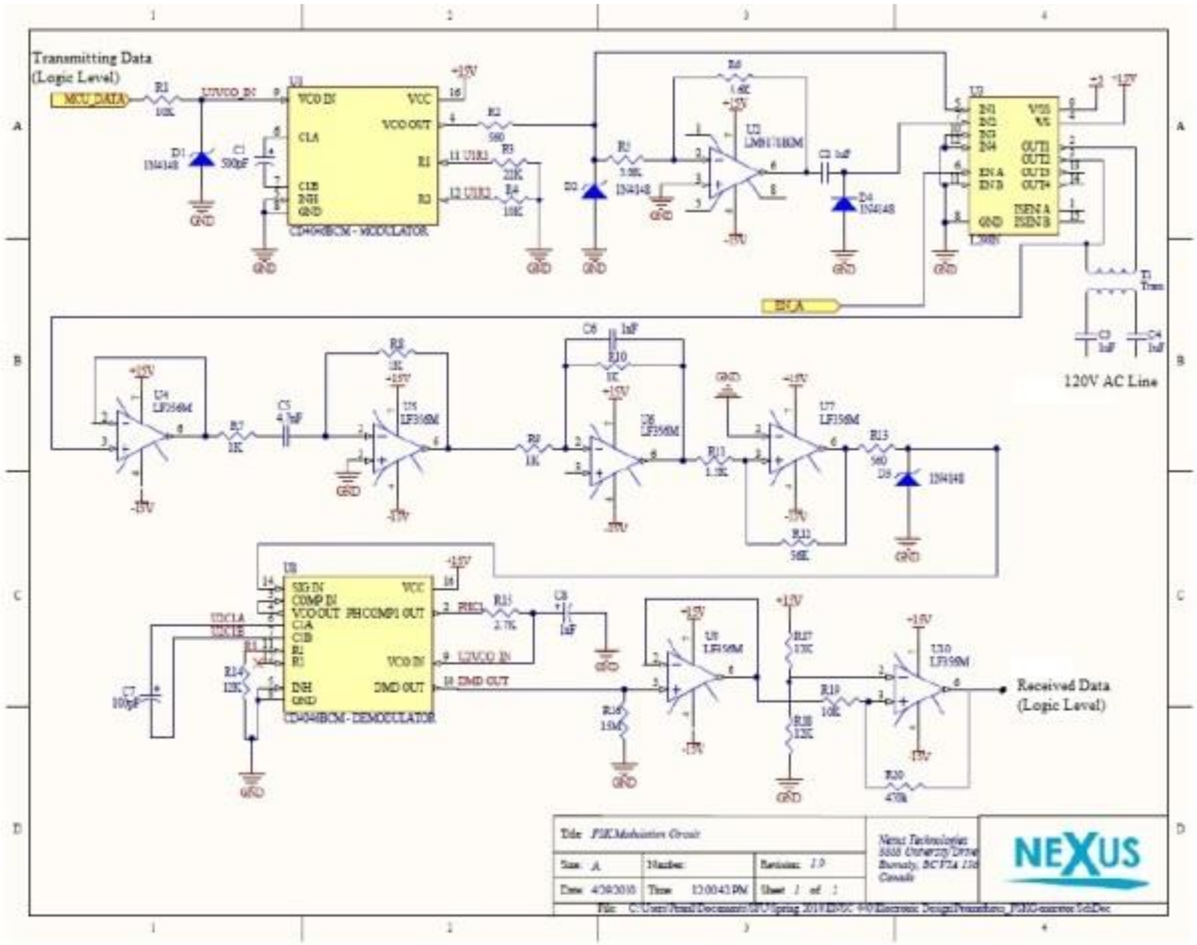
8.2 Master Controller's Block Diagram



8.3 Device Controller's Block Diagram



8.4 Power Line Communication Modem's Schematic



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More about Applying for IEEE Student Project Grants

The IEEE Standards Education Committee (SEC) offers grants of $500 for students and $300 for faculty mentors to help with graduate and capstone design projects that include an industry standards component. Students report on the results of these projects by writing and submitting Student Application Papers. The SEC reviews each final paper carefully and the accepted final papers are published to our Student Application Papers website.

Applications for the grants may be submitted at any time throughout the year, however the next upcoming deadline for fall 2011 is 15 October.

Frequently asked questions about the IEEE grants

1. **What are the grants for?** The grants are to help support students at colleges and universities worldwide with their design projects. The funds are generally used to purchase much needed materials to help students' projects succeed. The one absolute requirement is the projects include the application of industry standards.

2. **Who can apply?** Any college-level student planning to incorporate industry standards or specifications into their projects, and are in need of additional financial support. Keep in mind that students must produce a final paper, a Student Application Paper, that will be submitted to the Standards Education Committee (SEC) for review. If the SEC accepts the paper, it is published to the IEEE's website.

3. **Do I need to be an IEEE member and do the standards we use have to be IEEE standards?** The answer to both of these questions is no. The standards education grants are for all students worldwide, and as long as your project is using the appropriate technical standards for your project, the SEC requirements have been met.

4. **How do I apply?** Go to our Student Application Papers website: http://standardseducation.org/applications/. There you will find more information as well as the application and instructions, which is also linked below.

   - Application and Instructions (DOC, 61 KB)
   - The next upcoming deadline for applications is 30 January 2012 and the one after that is 15 March 2012.

Read successful final Student Application Papers.

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Contributions

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IEC IEEE Challenge

IEC-IEEE Challenge: The IEC and IEEE invite the world's Academics to submit papers that analyze the impact of electrotechnology (electricity & electronics) on economic, social and environmental development.

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Visit http://iecieeechallenge.org/.

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Conference will provide a forum for engineering and applied science faculty to share ideas about improving design-based capstone courses. The conference theme will be Industry Involvement.

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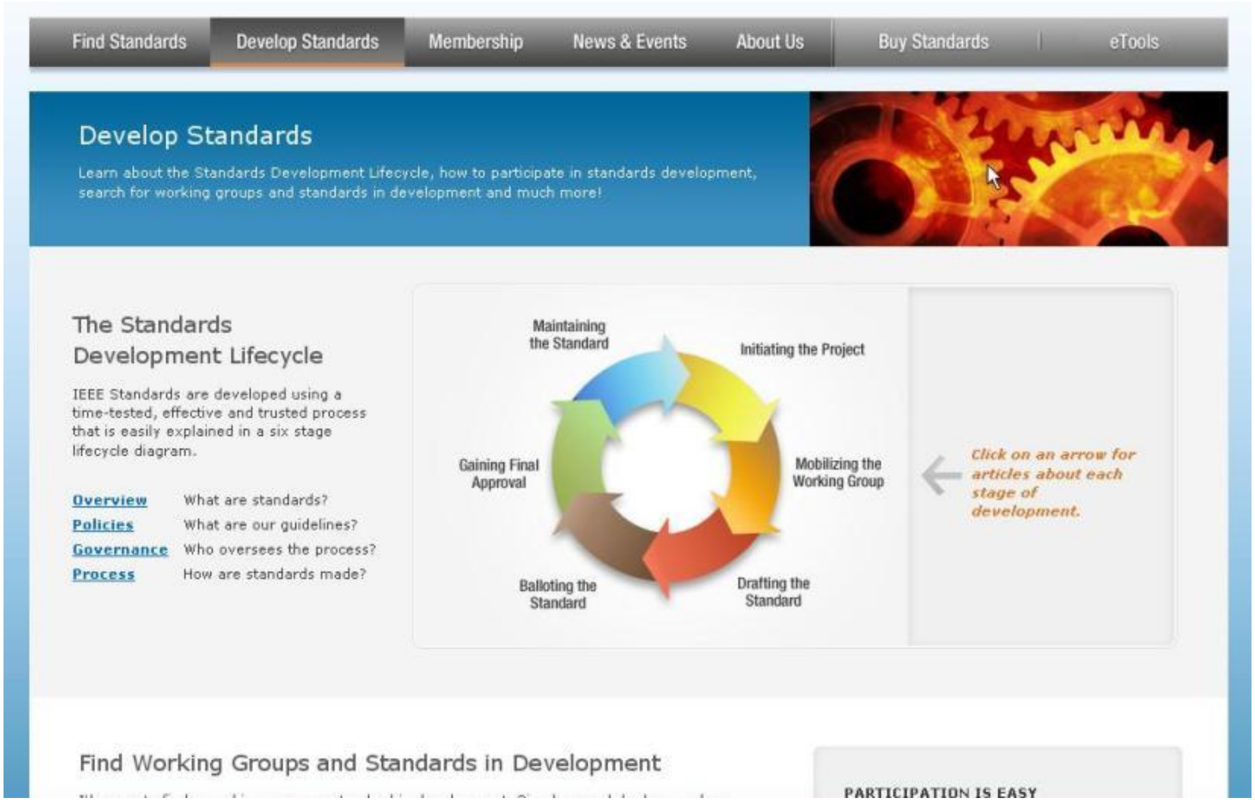
Standards Development Lifecycle



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Getting involved in the development of IEEE standards provides you the opportunity to network with industry peers, broaden your understanding of industry and technology, and gain familiarity with the content of standards in which you are involved—facilitating early compliance and anticipating market requirements.

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- Join invitation pools—to express your interest in voting or balloting on standards.
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Interested parties may submit an inquiry or article abstract for consideration to the Editorial Board at any time throughout the year via email to: ezine-eb@listserv.ieee.org.

Abstracts should be no longer than 500 words and final articles should be no more than 2,000 words.

Particular areas of interest include, but are not limited to:

- standardization activities in technical areas such as Networking Standards;
- impact and development of standards in various regions of the world;
- best practices and ideas for incorporating standards into the classroom and curricula.

Final contributions should include a 100 word biography of the author(s) and a high-resolution (JPEG) picture. All illustrations must be provided in a high-resolution (JPEG) format. References to all copyrighted material must be properly cited.

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IEEE Standards Education eZine Editorial Board

Yatin Trivedi, Editor-in-Chief, is Director of Standards and Interoperability Programs at Synopsys. He is a member of the IEEE Standards Education Committee (SEC), represents Synopsys on the Board of Directors of the IEEE-ISTO and at the Board of Directors of Accellera. He represents Synopsys on several standards committees and manages interoperability initiatives under the corporate strategic marketing group. He also works closely with the Synopsys University program.
Prior to joining Synopsys, Yatin was Senior Director of Strategic Partnership Programs at Magma Design Automation. He worked with Semiconductor IP and Library suppliers, and EDA tools vendors to establish comprehensive supply chain solutions around Magma's digital design implementation and analysis flows.

In 1992, Yatin co-founded Seva Technologies as one of the early Design Services companies in Silicon Valley. He co-authored the first book on Verilog HDL in 1990 and was the Editor of IEEE Std 1364-1995TM and IEEE Std 1364-2001TM. He also started, managed and taught courses in VLSI Design Engineering curriculum at UC Santa Cruz extension (1990-2001). Yatin started his career at AMD and also worked at Sun Microsystems.

Yatin received his B.E. (Hons) EEE from BITS, Pilani and M.S. Computer Engineering from Case Western Reserve University, Cleveland.

Amin Karim is the Director of Academic Outreach at DeVry University. Prior to this position, he served as the national dean of the college of technology for approximately eight years. Before joining DeVry in 1991, he served as an electrical engineer in the power and manufacturing industry and as a faculty and a department head of engineering technology program. He is a past Chair of the Electronics and Computer Engineering Technology Department Heads Association of the American Society for Engineering Education and served as a TAC of ABET evaluator for engineering technology programs. Currently, he is serving as the vice-chair of the Standards Education Committee for IEEE.

Wael Diab is currently a Senior Technical Director in Broadcom's Office of the CTO working on technical strategy for the Infrastructure and Networking Group (ING).

Wael is a Senior Member of the IEEE and Vice-Chair of the IEEE 802.3 Ethernet Working Group. He is a member of the IEEE-SA Standards Board, IEEE Standards Education Committee (SEC) and was elected to the IEEE-SA Corporate Advisory Group (CAG). He is a published author, coauthoring Ethernet in the First Mile: Access for Everyone, a book published by the IEEE, and was a contributing author to Broadband Services: Business Models and Technologies for Community Networks.

Wael holds BS and MS degrees in Electrical Engineering from Stanford University, a B.A. degree in Economics from Stanford, and an M.B.A. with honors from the Wharton School of Business. He has 57 issued US patents and has developed over 250 patents-pending in the networking space.

Bruce Harding is professor of mechanical engineering technology and coordinator of professional practice at Purdue University.

Professor Harding's scholarship and engagement activities revolve around the development and application of American National and ISO standards dealing with Technical Product Documentation (TPD) as it broadly relates to product realization, green manufacturing and other technical aspects of product lifecycle management (PLM).

He is active on a number of American National standards developing committees, and chairs the US Technical Activities Group (TAG) to ISO. He is ASME vice-president for Standardization and Testing, overseeing development of American National Standards for fasteners, geometric dimensioning and tolerancing, metrology, tools, pallets, threads, gaging, plumbing fixtures, metal mill products, chemical pumps, instrumentation, performance test codes and others.

Internationally, he has served as a US Delegate to APEC and has served as the Head of Delegation to ISO Technical Committee meetings in North America, Asia, Oceania, and Europe. Currently he chairs the 62-country ISO/TC10 committee on Technical Product Documentation, whose Secretariat is based in Sweden. The committee writes worldwide standards for technical product documentation for PLM.

Editorial Board Corresponding Members:

David Law is a Distinguished Engineer at Hewlett-Packard Networking and has worked on the specification and development of Ethernet products since 1989. Throughout that time he has been a member of the IEEE 802.3 Ethernet Working Group where he has held a number of leadership positions. He served as the Vice-Chair of IEEE 802.3 from 1996 to 2008 and in 2008 was elected to Chair of IEEE 802.3. David has been a member of the IEEE-SA Standards Board since 2005, has served as the Chair of IEEE-SA Standards Board Review Committee (RevCom) since 2008, and is currently serving as the Chair of the IEEE Standards Education Committee. In 2000 he received the IEEE-SA Standards Medallion for 'leadership and technical contributions to Ethernet networking standards' and in 2009 he received the IEEE Standards Association Standards Board Distinguished Service award 'For long term service to improve the operation and integrity of IEEE-SA governance'. David has a BEng (hons) in Electrical and Electronic Engineering from Strathclyde University, Glasgow, Scotland.

Donald Heirman is president of Don HEIRMAN Consultants, training, standards, and educational electromagnetic compatibility (EMC) consultation corporation. Previously he was with Bell Laboratories for over 30 years in many EMC roles, including Manager of Lucent Technologies (Bell Labs) Global Product Compliance Laboratory, which he founded, and where he was in charge of the Corporation's major EMC and regulatory test facility and its participation in ANSI accredited standards and international EMC standardization committees. He chair, or is a principal contributor to, US and international EMC standards organizations including ANSI ASC 63® (chairman), the Institute of Electrical and Electronics Engineers (IEEE), and the International Electrotechnical Commission's (IEC) International Special Committee on Radio Interference (CISPR) where in October 2007 he was named the chair of CISPR moving from the previous role as its subcommittee A chairman responsible for CISPR Publication 16. He is a member of the IEC's Advisory Committee on EMC (ACEC) and the Technical Management Committee of the US National Committee of the IEC.

In November 2008 he was presented with the prestigious IEC Lord Kelvin award at the IEC General Meeting in Sao Paulo, Brazil. This is the highest award in the IEC and recognizes Don's many contributions to global electrotechnical standardization in the field of EMC. He is a life Fellow of the IEEE and a life member of the IEEE EMC Society (EMCS) and a member of its Board of Directors, chair of its technical committee on EMC measurements, past EMCS president, newly elected vice president for standards, and past chair of its standards development committee. He is also past president of the National Cooperation for Laboratory Accreditation (NACLA). He is past president of the IEEE Standards Association (SA), past member of the SA Board of Governors and past member of the IEEE's Board of Directors and Executive Committee. He is also the Associate Director for Wireless EMC at the University of Oklahoma Center for the Study of Wireless EMC. He has presented numerous workshops, tutorials, and technical papers internationally and is listed in several Who's Who publications. Mr. Heirman is a retired Commander in the US Navy.

Geoffrey O. Thompson is the Principal of GraCaSI Advisory Services and a senior member of the IEEE and IEEE-SA. He is Member Emeritus of the IEEE 802 Executive Committee and former chair of 802.23 and 802.3. He has served has served in numerous IEEE-SA governance positions and is a member of the Registration Authority Committee. He has over 40 years of business experience with Xerox and Nortel and has worked in Manufacturing, Field Service, Research and Development, and Standards Development. He received the BSEE from Purdue University in 1964 and has 12 U.S. patents. Mr. Thompson has been awarded the IEEE Standards Medallion and the IEEE Standards Board Distinguished Service Award.

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