Director’s Message

By Aaron Hussey

As 2016 is more than half-way over, consider the remaining opportunities that are available to you through ISA’s Power Industry Division (POWID). Firstly, contributions to newsletters like this are always welcome—you will have one more opportunity for the third newsletter. If you have a technical article, interesting find, or book description, please let the newsletter editor, Dale Evely, know. Secondly, ISA 67 Nuclear Power Plant Standards and ISA 77 Fossil Power Plant Standards committees have several subcommittees that are drafting new standards. Thirdly, the 60th Annual POWID/EPRI Controls & Instrumentation Symposium will be held in June, 2017 and the Planning Committee is being finalized. If you would like to be a volunteer such as a Session Developer or Paper Reviewer, please contact Seth Olson at seth.olson@chevron.com.

The summer POWID newsletter provides you with an opportunity to consider your involvement in the division throughout the remainder of 2016 by reflecting on some of the activities that have taken place and will be taking place. Please consider how giving some of your time, personally and professionally, is mutually beneficial for society and for you. As you consider, ask yourself how your specific talents and experience could assist the division and let me or someone else you know in POWID respond with some opportunities by emailing or giving us a call.

Aaron Hussey
POWID Director 2015/16
ahussey@expmicrosys.com

2016 ISA POWID Symposium Supporters

Platinum Champion

Gold Champion

Silver Champions

Media Sponsors

Upcoming POWID and ISA Events

60th Annual ISA POWID Symposium
June 2017 (dates and location not yet finalized)
For updates see: https://www.isa.org/division/powid/

ISA Fall Leaders Meeting
Saturday, 24 September – Monday, 26 September 2016
Newport Beach Marriott Resort & Spa
900 Newport Center Drive
Newport Beach, California 92660-6206

You can find information on other ISA events at www.isa.org/events.
As I write this we are just a few weeks past a very successful ISA POWID/EPRI Symposium, and if you were not able to attend you missed an excellent opportunity to network with and to learn from the experiences of others in our industry. The Symposium is always a technical highlight for my year. Now is the time to start laying the groundwork with your management so that you will have their support to participate next year. One way that can help is if you volunteer to write a technical paper for presentation at the Symposium. A paper will provide positive exposure both for you but also for your company. Consider the early Call for Papers that appears in this edition of the newsletter as an opportunity that needs your careful consideration.

Another path to positive exposure for both you and your company would be to have an article published in this newsletter. Technical content that is specific to the automation side of the power industry is what provides the best benefit to our membership. We are also interested in historical items and items of general technical interest. You can send your articles to dpevely@southernco.com (please limit any attachments to 5MB or my mail server may not let them through and I will never know that you tried to send them). If you e-mail an article and do not get a thank you response from me it may not have gone through. Please keep in mind that articles need to be non-commercial in nature so don’t include a heavy sales pitch as a part of the technical content.

If you have attended any of the past ISA Symposiums you had a chance to meet Rodney Jones, who has served as ISAs Ambassador to the public at these events for a number of years. Rodney has been a key part of the success of the Symposiaums and the Division through the tremendous amount of support he has provided to both. Rodney has now transitioned to a new role at ISA and we will miss him.

I would like to thank everyone who contributed to this edition of the POWID Newsletter; we all have regular work to do and we appreciate it when you make the extra effort to go beyond that by contributing to this newsletter.
More than 150 professionals in the power generation industry gathered in Charlotte, North Carolina last week to assess the energy sector’s most pressing challenges relating to automation and instrumentation, and to outline strategies and solutions to overcome them.

ISA’s 59th Power Industry Division (POWID) and Electric Power Research Institute (EPRI) Symposium, held 27–30 June, featured more than 70 technical paper presentations along with expert speakers and a diverse range of panel discussions, tutorials, vendor exhibitions, and other value-packed activities.

Attendees met face to face with the leading authorities and thought leaders at the pulse of change in the energy industry and gained the critical insights and perspectives needed to stay ahead in the rapidly evolving energy marketplace.

Sessions addressed the key factors influencing:
• All forms of energy, including nuclear, fossil fuels, hydro and renewables
• Data security and demands for improved industrial cybersecurity
• Reliable, efficient power generation and delivery
• Advanced technologies and emerging applications

Each year, ISA’s POWID Symposium is viewed as the "can’t-miss" event for learning about the latest industry innovations; staying informed of vital regulatory requirements and updates; and networking with a wide range of power generation professionals.

ISA partnered with EPRI—which conducts research on key challenges in the generation, delivery and use of electricity—to conduct this high-profile event. With robust energy-related research, development and engineering operations, and more than 260 companies tied to the energy sector, the city of Charlotte was a fitting venue for the gathering.

Highlights of the agenda included:
• Addresses by noted industry experts included: Bernie Cook, Director of Maintenance and Diagnostics at Duke Energy, Tom Alley, Vice President of the Generation Sector at EPRI, Ramesh (Rudy) Shankar, Ph.D., MBA, Professor at the Energy Production Infrastructure Center (EPIC) at the University of North Carolina Charlotte; Robert Romanosky, Ph.D., Advanced Research Technology Manager at the National Energy Technology Laboratory within the US Department of Energy; Randy Bickford, President of Expert Microsystems, Inc; Damien Faille, Research Engineer, Expert System, Dynamics, and Optimization at EDF, and Matthew Gibson, Principal Technical Leader focused on Cybersecurity at EPRI.
• A Vendor Exhibition that showcased leading industry companies and information on their latest products, technologies and services. Corporate sponsors and exhibitors included: ABB, Beamex, Emerson Process Management, Honeywell, MissionSecure, Owl, Phoenix Contact, Rkneal, Schneider Electric and Ultra Electronics.
• There were approximately 170 registered attendees for the Symposium, exhibits, and/or working group meetings with over 70 technical papers rounding out a comprehensive 3 day technical symposium.

Also on the agenda were ISA67 and ISA77 I&C Standards working group meetings and the annual ISA POWID Honors and Awards Event.
Power Generation: Automation, Control, and Sensing Solutions for Flexible Operations

The 60th Annual ISA POWID Symposium is the largest conference dedicated to automation, control systems, and instrumentation in the power generation industry. The symposium program committee is soliciting abstracts for full papers and for presentations. All paper submissions will be peer-reviewed to ensure high quality and originality. Symposium proceedings will be published in the conference proceeding for distribution to attendees and also made available on the ISA website. Suggested topics for submissions are as follows:

**Fleetwide**
- Equipment Development
  - New Sensors
  - Wireless Sensor Applications & Standards
  - Fieldbus
  - Embedded Sensing
- Human Factors Engineering
  - Alarm Management
  - High Performance HMI
  - Control Center Design
- Fleet Management
  - Inspection and Maintenance
  - Condition Monitoring Systems
  - Alarm Management
  - Training the Next Generation
  - Monitoring and Diagnostics
  - Big Data
  - IIoT
- Fossil
  - Environmental Control Systems
    - Scrubbers
    - SCR Controls
    - Regulatory Challenges
    - MATS Compliance
- Combustion Turbine and Combined Cycle Plants
  - Operational Flexibility
  - Start-up and Ramp Rates
  - Load Range Extension
- New Generating Plants
  - IGCC
  - Regulatory Challenges
  - Cycling
  - Operation Flexibility
- Renewable and Distributed Generation
  - Optimization of Renewable Power (hydro, wind, solar, biomass, etc.)
  - Thermal Cycle Augmentation for Renewable Steam Power
  - Energy Storage Challenges
    - Process Modeling and Predictive Controls
    - Long term Reliability and Maintenance Issues
    - Renewable Power Forecast and Management
- Nuclear
  - Operating Nuclear Plants
    - Analog to Digital Changes
    - Plant Life Extensions
    - EMI Testing and Immunity
  - New Nuclear Plants
    - Conventional Commercial Reactors
    - Small Modular Reactors
    - Regulatory Challenges
- Programmatic Issues
  - Setpoints, Uncertainties, and TSTF-493 Implementation
  - Commercial Grade Dedication
  - Operability Determinations
  - Suspect and Counterfeit Parts
- Cybersecurity
  - NERC CIP Requirements
  - Implementation & Audits
  - Testing & Intrusion Detection
  - Like for Like Module Replacement

For more information on the 60th ISA POWID Symposium and to submit an abstract, please go to [www.isa.org/powersymp](http://www.isa.org/powersymp) or contact:

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seth.olson@chevron.com

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**PROGRAM CO-CHAIR, CYBERSECURITY**
Michael Firstenberg
MichaelF@waterfall-security.com

Abstract Due: .................................................................27 January
Draft Paper Due: ............................................................24 February
Final Paper Due: ............................................................28 April
Rights and Responsibilities Form Due: ..........................5 May
Draft Presentation Due: ..................................................5 May
Final Presentation Due: ..................................................19 May
ISA POWID Goals: 2016 Status

By Aaron Hussey
POWID Director 2015/16

In 2014, ISA developed and implemented a new vision for aligning its vision and mission to strategic goals that, when implemented, will align the needs of key stakeholders with the membership as a whole (www.isa.com/strategicgoals). In 2016, the Power Industry Division adopted the framework (see figure below) that was established by the vision. This article highlights the status of some of the key activities that are taking place within POWID during 2016 in order to deliver value to its membership while also meeting the goals that support ISA’s vision.
POWID will develop timely, relevant content on important topics to meet the career enhancement and professional development needs of automation within the electric power industry.

![Graph showing goal status over time]

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<tr>
<th>Objective</th>
<th>Actions</th>
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<tbody>
<tr>
<td>Provide strong technical programming at annual controls &amp; instrumentation symposium</td>
<td>tracks</td>
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<td></td>
<td>Add Industrial Internet of Things (IIoT)/Big Data focus in technical tracks</td>
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<tr>
<td></td>
<td>Continue session on Monitoring &amp; Diagnostics (M&amp;D)</td>
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<td></td>
<td>Continue student session and networking reception</td>
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<td></td>
<td>Continue session on Cyber Security</td>
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<tr>
<td>Develop standards in fossil (77) and nuclear (67) power</td>
<td>Identify collaborative opportunities in 67 &amp; 77 standards between ISA, EPRI, and other organizations</td>
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<td></td>
<td>Continue 77 standards in progress by continuing subcommittee meetings</td>
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<td></td>
<td>symposium</td>
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<tr>
<td>Address industry needs in training</td>
<td>Review training courses and identify new areas of focus</td>
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<td>Offer at least one highly relevant course during annual symposium</td>
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<td>Present relevant content to the membership</td>
<td>Assemble and publish a newsletter three times a year with content relevant to our membership</td>
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<td></td>
<td>Update and maintain the POWID website to provide an always available portal to information about POWID and its activities</td>
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<td>Archive all POWID technical papers (1959 – Present) in ISA Technical Paper database</td>
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POWID will use data to understand trends, make decisions, and develop products and services that align with market needs.
Coolest Delivery

POWID will deliver industry-leading content via multiple platforms in an engaging, easy-to-use, and interactive way.

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<th>Objective</th>
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<tbody>
<tr>
<td>Utilize web-based technologies to deliver content and messaging</td>
<td>Conduct a web cast with best technical paper from symposium</td>
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<td>Continue using mobile app for annual symposium</td>
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<td>Advertise annual symposium with video feedback of prior attendee</td>
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<td>Continue and improve social networking through LinkedIn</td>
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<tr>
<td>Identify a plan to transition to more streamlined delivery of information</td>
<td>Scope a plan for transitioning delivery of key information to a virtual platform</td>
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Cybersecurity

POWID will utilize ISA’s resources and expertise related to the cybersecurity of automation and control systems used across the electric power industry.

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<tr>
<th>Objective</th>
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<tbody>
<tr>
<td>Provide a platform for presentation and discussion of the latest industry activities in Cyber Security</td>
<td>Continue track on Cyber Security at POWID 2016</td>
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<td></td>
<td>Communicate availability of ISA’s cyber security standards and publications to target market for annual symposium and membership</td>
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<tr>
<td>Collaborate with leading industry organizations to addressing cyber security concerns</td>
<td>Identify areas for collaboration on cyber security with EPRI, ISA, and other relevant organizations</td>
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Advocacy

POWID will increase understanding and awareness of automation across all age groups, resulting in enhanced proficiency of automation as a profession.

For more information on POWID’s goals for 2016, contact Aaron Hussey at ahussey@expmicrosys.com.
ISA Power Industry Division 2016 Honors and Awards Event

Held during the 2016 ISA POWID/EPRI Symposium, Charlotte, NC

The first portion of the Honors and Awards program recognized our dedicated volunteers, keynote speakers and Champions that made this year’s ISA POWID/EPRI Symposium possible. The second portion presented the POWID awards for outstanding contributions.

First, our welcome and keynote speakers were presented with certificates.
- The ISA welcome speaker: ISA President, Jim Keaveney
- Our keynote speakers: Tom Alley; Ramesh Shankar, Ph.D.; Robert Romanosky, Ph.D.; Bernie Cook; Randy Bickford, Ph.D.; Damien Faille and Matt Gibson

Next, our Symposium Champions were recognized, as their financial contributions make the Symposium possible:
- Platinum Champion – MSi
- Gold Champion – Emerson
- Silver Champion – ABB
- Silver Champion – Honeywell
- Silver Champion – Schneider Electric
- Media Sponsor – POWER Magazine

The dedicated POWID volunteers who plan, organize and orchestrate the symposium were recognized:
- General Chairperson – Susan Maley
- Program Chairperson – Seth Olson
- Program Co-Chairperson – Sydni Credle
- Program Co-Chairperson – Michael Firstenberg
- Program Co-Chairperson – Chad Kiger
- Program Co-Chairperson – Xinsheng Lou
- Program Co-Chairperson – Rick Meeker
- Program Co-Chairperson – Jeff Williams
- Program Paper Chairperson – Terri Graham
- POWID Web Page Coordinator – Cyrus Taft
- Program Session Developer – Edson Bortoni
- Program Session Developer – Benjamin Chorpening, Ph.D.
- Program Session Developer – Omar Faruque, Ph.D.
- Program Session Developer – Josiah Long
- Program Session Developer – Prokash Paul
- Program Session Developer – Paolo Pezzini
- Program Session Developer – Jay Pritchett
- Program Session Developer – Bob Queenan
- Program Session Developer – Steven Seachman
- Program Session Developer – John Sorge
- And our ISA POWID Director – Aaron Hussey

Next, the POWID awards for outstanding contributors were presented.

Each year the ISA Power Industry Division presents its most esteemed awards to outstanding individuals and facilities nominated by ISA members.

- The Robert N. Hubby Academic Scholarship is POWID’s most esteemed scholarship and is awarded to a deserving student meeting the rigid technical requirements.
- The Service Award is for outstanding service in the field of instrumentation. The service of the individual must be noteworthy, exemplary, and exceed the normal duties of the office held. The service is of a nature that advances the stature of the Power Division and/or ISA.
- The Facility Award was created to honor facilities that demonstrate innovative application of control systems or instrumentation technology within the power industry.
- The Technical Paper Awards are awarded to the authors of the top 3 technical papers that were voted best by the paper reviewers and the Executive Committee members. This year the papers presented at both the 2015 and this year’s 2016 POWID/EPRI Symposium are being honored.
- The Achievement Award is for the purpose of recognizing an individual whose efforts have advanced the generation of power. These efforts are exemplified through the individual’s outstanding achievements, original design application, or special contributions toward the development of engineering concepts in the field of instrumentation and controls within the power industry.

The Robert N. Hubby Academic Scholarship Award

The technical requirements are the following:
- Two reference letters that should comment on the applicant’s character and potential leadership, or for making a significant contribution to the instrumentation, systems, and automation profession in the Power Generation Industry.
- Academic record based on an original transcript
- Awards and Honors / Extracurricular Activities
- Employment History
- An essay that shall describe his or her ambitions and qualifications as an innovator or future leader in a career in the instrumentation, systems, or automation field within the Power Generation Industry. Applicant shall describe his or her career objectives and how the award of the ISA Power Industry Division academic scholarship would help him or her to attain his or her objective.

The ISA Power Industries Division was proud to bestow the Robert N. Hubby Academic Scholarship Award to Ivan Petrovic, Chemical Engineering, Washkewicz College of Engineering at Cleveland State University, Cleveland, OH.
The ISA POWID Service Award

This year’s recipient of the POWID Service Award was Terri Graham of Hurst Technologies.

Terri Graham has contributed to the ISA Power Industry Division by coordinating paper review and submissions for the annual symposia for many years. In this role, Terri coordinated the administration of the abstract submittals, paper and presentation submittals, paper reviews, and copyright release forms. Her efforts have ensured that content is delivered on-time, within quality expectations, and support ISA’s content delivery goals.

The society as a whole has been well-represented by the Power Industry Division consistently as a result of the relentless effort of Terri Graham and the behind-the-scenes support that she has provided. Many of the papers that are published in the symposia proceedings continue to be used as references for industry efforts in applying automation topics to end-use. Additionally, symposia proceedings also provide a source for further publication of content such as through the newsletter and ISA website. The quality of the publications and end-use application would not be possible without the role that Terri fulfills. This particular responsibility requires a tremendous amount of administrative effort and is paramount to the success of the division. The ISA Power Industries Division was proud to bestow the 2016 Service Award to Terri Graham.

The ISA POWID Facility Award

This year’s recipient of the ISA POWID Facility Award was Alabama Power Company’s, E.C. Gaston Plant.

The Alabama Power Company, E.C. Gaston Plant is a 1,880,000 MW plant, consisting of 5 units located along the Coosa River outside of Birmingham, Alabama. Units 1 through 4 are subcritical units capable of using coal or gas as their primary fuel. Unit 5 is an 880 MW supercritical unit on pulverized coal that is also capable of 450 MWs on natural gas. Located on the Gaston site adjacent to Unit 5 is the U.S. Department of Energy NETL National Carbon Capture Center.

Plant Gaston has served as the host site for a number of US DOE NETL and EPRI research efforts over the past quarter century.

The original Power Systems Development Facility (PSDF) Sponsored by the U.S. Department of Energy (DOE) in operation since 1995, applied a small-pilot scale test center on the Plant Gaston site to develop several types of first-of-a-kind technologies and successfully integrated these components into a reliable gasification process for scale-up to commercial applications. Two significant achievements include a gasifier suitable for use with low rank fuels, and a hot gas filtration to improve energy efficiency; both of these technologies are included in an integrated gasification combined cycle power plant presently being constructed.

Plant Gaston now hosts the U.S. Department of Energy NETL National Carbon Capture Center, a focal point of national efforts to develop advanced technologies to reduce greenhouse gas emissions, such as CO₂ capture, from coal-fired power plants by offering infrastructure that bridges the gap between lab-scale research and large demonstration projects. This testing has resulted in a scale-up to commercial power plant operation for one solvent and scale-up for further testing at larger facilities for five other solvents. The center continues to promote the development of innovative CO₂ capture processes—membranes, enzymes, and sorbents—that could offer more significant cost savings.

Plant Gaston hosted the Monitoring & Diagnostics Center (2007)—an EPRI sponsored R&D pilot project of a fleet-wide scale monitoring and diagnostics center that uses advanced pattern recognition technology to monitor plant equipment for anomalous conditions prior to failure, saving avoided costs. The pilot was successful, leading to a full-scale deployment across all of Southern Company that has saved millions of dollars in O&M costs. Some of the findings include:

- Operators trust people more than technology
- “We Report—You Decide” is a successful approach
- If it might cause the plant difficulty, call then follow up with email
- Choose experienced staff to operate the Center
- Build a consistent set of simple pattern recognition models for each unit
- Heat rate improvements can contribute a lot of benefit
- Watch for best performers and facilitate information sharing between plants

Wireless Sensors (2010)—several standards-based, low-cost wireless technology sensor platforms were tested at Plant Gaston for enhancing the ability to monitor key equipment and established that such networks can be used in plant environments even with large piping, concrete structures, steel beams, and processing operations.

Currently, Plant Gaston is serving as the host site of many EPRI sponsored projects on control system design and diagnostics including the following:

- Model Predictive Control
- Iterative Feedback Tuning
- Robust Augmentation of PID Clusters
- Demonstration of Automated Tuning Packages
- Demonstration of Control System Health and Diagnostic Technologies.
- Asset Management Information Optimization (2015) and the pilot site for Southern Company’s Smart M&D effort
- Expanded data collection and advanced sensing
- Mobile workforce
- Data fusion and visualization
- Anomaly detection, automated diagnostics, and prognostics

Plant Gaston participated in the NERC CIP V5 pilot and their security measures were used as a model for reducing potential security impacts across the industry.

These ongoing efforts to develop and demonstrate technology advancement, exemplifies Plant Gaston’s goal of developing new technologies and seeking O&M cost savings strategies, while also sharing valuable insights that will assist the industry at-large with adoption and furtherance of technological innovations.
Best POWID Technical Papers

Traditionally, each year POWID has historically recognized the best papers from the previous year’s symposium. We have been able to take advantage of our on-line paper reviews and speed up the process with the help of our Paper Review Coordinator, Terri Graham. This year POWID recognized the best paper from both 2015 and 2016. The three best papers from 2015 and 2016 are:

Best POWID Technical Papers—2015

Best Paper
Measuring Fluid Level at Subcritical to Supercritical Pressures in Once Through Boilers
by Jeff Klaas, Bernie Begley, Don Labbe

2nd Best Paper
Installation of Spent Fuel Pool Instrumentation for LA-12-051 at D.C. Cook Nuclear Plant
by Pete Vande-Visse, Matthew Britten

3rd Best Paper
Progress on a Raman Gas Analyzer for Power Industry Applications
by Benjamin Chorpening, Ph.D., Emma Johnson, Michael Buric, Steven Woodruff

Best POWID Technical Papers—2016

Best Paper
Application of Model Predictive Control (MPC) to Improve Steam Temperature Control on a Pulverized-Coal Unit
by Cyrus Taft, John Sorge, Mircea Lupu, Rick Kephart

2nd Best Paper
Advanced Gas Turbine Combustor Health Monitoring Using Combustion Dynamics Data
by Bobby Noble, Leonard Angello, Ben Emerson, Tim Lieuwen

3rd Best Paper
Patch Theory: Robustness/Performance Enhancement Of Power Plant PID Control Clusters Through Analytical Design
by Joseph Bentsman, Cyrus Taft, John Sorge, Huirong Zhao, Insu Chang

And our final and most prestigious award; The ISA POWID Achievement Award:

This year’s recipient of the POWID Achievement Award was John Sorge of Southern Company.

John Sorge has been an active member of the electric power generation Instrumentation and Control community for over 35 years. During this time he has advocated, sponsored, and technically participated in activities, projects and organizations to advance I&C research and technologies for the evolving generation fleet. During the late 1980s and 1990s, John was an integral member of the research effort that led the industry in the US Department of Energy’s Clean Coal Technologies demonstrations of NOx reduction technologies. These demonstrations had a clear and measurable impact on the rulemaking and the eventual deployment of these technologies by utilities.

Lastly, our sincere thanks to the ISA staff who poured in tremendous effort to make the POWID Symposium successful: Kim Belinsky, Rodney Jones, and Chesley Grove.
Presentation of MSI Platinum Champion Recognition

John Sorge’s memorable Achievement Award acceptance speech (you just had to be there to appreciate it)

Cyrus Taft and John Sorge accept the 1st Best Paper for POWID 2016 award from Aaron Hussey

John Sorge accepting the Achievement Award from ISA POWID

Seth Olson accepting the Program Chair Award from Susan Maley
John Sorge accepting the Achievement Award

Dan Lee accepting from Susan Maley the Conference Silver Champion Award for ABB

Session Developers: John Sorge, Ben Chorpening, Josh Long, Paolo Pezzini and Bob Queenan with Susan Maley

Aldin Francisco of Alabama Power Company accepting the POWID 2016 Facility Award from Aaron Hussey

Joseph Bentsman and John Sorge accept the 3rd Best Paper for POWID 2016 award from Aaron Hussey

Ben Chorpening accepts the 3rd Best Paper for POWID 2015 award from Aaron Hussey
ISA Senior Membership and New ISA POWID Fellows

By Dale Evely, P.E.
Southern Company
ISA POWID Newsletter Editor

Do you have ten years of active work experience in the instrumentation, systems, and automation field? Your education and experience may qualify you to be an ISA Senior Member. Being an ISA Senior Member provides you with added recognition of your accomplishments in the industry and looks good on a resume as well.

An ISA member or applicant who has graduated from a baccalaureate engineering or science curriculum, with at least six years of active work experience in the instrumentation, systems, and automation field (two of which have been in a position of responsible charge) may apply for this membership grade. If not a graduate, the member/applicant must have 10 years of active work experience in the instrumentation, systems, and automation field (two of which have been in a position of responsible charge).

Current ISA members may apply for Senior Member. Non-members must join ISA first and then apply for Senior Member status.

One of the reasons to apply for Senior Member when you are eligible for it is that you are not eligible to be nominated for ISA Fellow member grade if you are not already a Senior Member of the Society. A number of ISA POWID members are already ISA Fellows and two were just recently promoted to that membership grade. These two most recent ISA POWID connected Fellows are to be congratulated and they are:

Chad J. Kiger
Oak Ridge Section and Power Industry Division
Analysis & Measurement Corp. Knoxville, Tennessee, USA
For contributions to development of standards and guidelines for electromagnetic compatibility testing and for innovative voice and data wireless technology

Xinsheng Lou
Power Industry Division
GE Power, Windsor, Connecticut, USA
For contributions to development of control and optimization technologies for emerging clean coal power plants and conventional pulverized coal fired boilers

Chad and Xinsheng will be formally presented with Fellow member grade and recognized publically for it at the 54th Annual ISA Honors & Awards Reception and Gala on September 24th in Newport Beach, California.
Collaborating to Understand Cybersecurity in Power Generation

By Justin Thibault
Senior Technical Leader
Electric Power Research Institute

Advances in automation and smart components are opening up a world of possibilities for improved efficiency and effectiveness in power generation, but these gains will not be fully realized unless automation professionals partner with their cybersecurity counterparts. Because while these advanced industrial controls systems are designed to remove the human element, user behavior remains their Achilles heel:

- In the Stuxnet attack, the threat actors took advantage of the liberal sharing of ubiquitous USB drives among users to bypass an air-gapped network. (https://www.wired.com/2014/11/countdown-to-zero-day-stuxnet/)
- In the Energetic Bear/Crouching Yeti/Dragonfly, the threat actors used a combination of insecure e-mail to send clean links to compromised sites, understanding that system administrators were keen to download and apply patches when they could without verifying file integrity. (http://www.darkreading.com/attacks-breaches/energetic-bear-under-the-microscope/d/d-id/1297712)
- The 2015 Ukrainian attacks involved installing malware by exploiting vulnerabilities in presentation and word processing software used on critical networks. (https://ics-cert.us-cert.gov/alerts/IR-ALERT-H-16-056-01)

New threats bring new policies and procedures, usually from those tasked specifically with cyber security, but security through compliance has proven to be an ineffective strategy. Consider the previous examples—severely restricting USB access could have kept Stuxnet from spreading; the Energetic Bear/Crouching Yeti/Dragonfly depended on the security of third parties, which is even more challenging. And completely locking down every user’s office applications is impractical.

To realize the potential of emerging automation solutions, automation experts must engage cyber security experts and collaborate with their peers in the power industry in three areas—education about best practices, collaboration on assessment methodologies, and leveraging proven O&M best practices. The Electric Power Research Institute’s (EPRI’s) Generation Sector is working with its member companies in these areas:

- A collaborative of more than 20 EPRI members has developed topical guidelines and Computer Based Training (CBT) on best practices for securing I&C systems. R&D topics included interactive remote access, patch management, security status monitoring, control network scanning, hardening cyber assets, and access and permission management.
- EPRI members are also optimizing asset assessment in a methodology that will produce a Cyber Security Data Sheet (CSDS)—similar to the Material Data Safety Sheet (MSDS)—for controls components, describing the vulnerabilities and configuration options available for mitigation. This type of concise and easy-to-understand output can educate users on security and inform policies and procedures. As these are developed, EPRI will store them in a Reference Assessment Library so best practices can be shared.
- The U.S. Department of Energy (DOE) developed the Cyber Security Capability and Maturity Model (C2M2) to provide organizations a self-assessment method for expanding cyber security awareness and practices across any size organization or subdivision. EPRI’s Operations, Maintenance, and I&C programs are matching best practices and emerging methods to this model to provide members knowledge to leverage proven methods in areas including configuration management and incident response for better cyber security.

The changes in power markets and resulting demands on utilities do not allow for automation and connectivity to be passed over out of fear and misunderstanding.

The Third Best Technical Papers from the 2015 and 2016 ISA POWID Symposia

During the Honors and Awards Luncheon in June 2016, Awards for the Third Best Papers for the 2015 and 2016 POWID Conferences were presented as follows:

2015: Benjamin Chorpening, Emma Johnson; Michael Buric and Steven Woodruff for the paper entitled “Progress on a Raman Gas Analyzer for Power Industry Applications”

2016: Joseph Bentsman, Cyrus Taft, John Sorge, Huirong Zhao and Insu Chang for the paper entitled “Patch Theory: Robustness/Performance Enhancement of Power Plant PID Control Clusters Through Analytical Design”

These technical papers are provided in their entirety in this newsletter for your reading pleasure.
Progress on a Raman Gas Analyzer for Power Industry Applications

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Keywords: fuel gas composition, spectroscopy, Raman, gas turbine

Abstract

The Raman Gas Analyzer (RGA) has been recently developed to be a fast, non-destructive instrument for on-line measurement of gas composition. The Raman Gas Analyzer is capable of reporting the concentrations of multiple species simultaneously, with sampling times below one second for process control applications in energy or chemical production, such as adjustments in gas turbine engines to enable optimal control based on the changes in fuel composition. The instrument is based upon using a hollow-core capillary waveguide with a reflective lining as a flow-through sample cell. The effect of using such a waveguide in a Raman process is to integrate Raman photons along the length of the sample-filled waveguide, greatly improving the optical collection efficiency in gas applications. Two pre-commercial field prototypes have been constructed by NETL, and they are being tested for potential use in energy applications such as coal gasification, turbine control, well-head monitoring for exploration or production, and non-conventional gas utilization, and chemical looping. Reported here are results from application of the RGA to a 50 kW chemical looping reactor and a study on the lower detection limits of the RGA.

Introduction

Although renewables are increasing in total power generation, fossil energy sources (mostly coal and natural gas) will continue to provide most of the electrical energy production in the United States for the foreseeable future [1]. To help minimize pollutant emissions, and improve fuel flexibility, better instrumentation for monitoring and control of large-scale power generation systems are needed. A fast and accurate gas composition sensor provides the opportunity to implement control strategies that take into account the chemical composition of the fuel gas. The introduction of Carbon Capture and Storage technologies provides additional challenges by adding the requirements for gaseous byproduct separation, feed stream analysis, and control of the process. This paper discusses progress on a novel instrument based on enhanced spontaneous-Raman spectroscopy [2, 3], which is capable of real-time sensing for process control of advanced energy systems.

The NETL Raman Gas Analyzer (RGA) was developed for energy-process control based on gaseous input or output composition [3]. As part of the development, the detection limits for several species of interest in power generation applications have been investigated. The RGA (field prototype in Figure 1) is being applied to fossil energy research experiments at NETL, including natural gas fired combustion experiments, and a small scale chemical looping reactor. In parallel, the technology has been licensed to an instrument company, and a commercial version of the RGA is anticipated within a
A number of gas sensing devices are currently used to monitor some of the relevant species in power generation applications. Unfortunately, fundamental limitations of these devices often prevent the possibility of achieving real-time control in a power generation system. The rate of gas consumption is often too rapid for conventional instruments to provide composition data before the gas is used in the system. One alternative technology is the gas chromatograph (GC). The GC utilizes an elution column and one or more detectors to separate species in a time-resolved fashion. This method is very slow, since elution through a column requires several minutes in order to distinguish species of different masses. Gas chromatographs also require frequent maintenance, calibration, and replacement of columns after contamination with liquid water or particulates. While they often provide accurate results when maintained properly, the GC has severe limitations for real-time control applications due to the intrinsic speed limitation. Another alternative to technology to the RGA, a mass spectrometer (MS) can be tailored to perform fast analyses, but often requires significant sample separation or pressure reduction at the input, as with compound GC/MS systems. The sample preparation stage leads to the GC/MS systems retaining the slow characteristics of GCs. The fastest MS systems for multispecies analyses still generally require 5 or more seconds per scan, depending on the accuracy needed. Another alternative to the RGA, electrochemical type resistance sensors are inherently limited in speed by the rate of oxidation/reduction reactions, which at reasonable operating temperatures usually result in response times on the order of several tens of seconds.
Optical methods of gas measurement include infrared (IR) optical absorption, atomic emission, and Raman spectroscopy. The IR absorption measurement systems generally either employ a broadband or a tunable laser source (TDLAS) with either a dispersive or Fourier transform (FTIR) type detection system. While it is a successful method for a number of species, IR absorption cannot measure the homonuclear diatomics (including H₂, N₂, O₂). IR systems also are impacted from significant water absorption bands, making accurate characterization more difficult. A tunable laser source requires additional control and stabilization and may only access one or two spectral lines from one or two species of interest. In contrast, spontaneous Raman is probably the most versatile and straightforward for multi-species measurement.

Raman has long been limited to a laboratory-only technique because of the small magnitude of Raman scattering signals that can be collected from a gas with free-space optical configurations. While Raman microscopes for solid or liquid samples are common, Raman sensing for gases is much more difficult due to the low densities and low Raman cross-sections of most gases of interest. The early research on this project resulted in the implementation of a micro-bore sized capillary waveguide in an optimal configuration for collection of spontaneous Raman scattering inside the hollow waveguide core [4]. This configuration was shown to increase the collection efficiency of the scattered Raman light by a factor of 1000 or more versus free-space collection with conventional optics. Using this in an industrial instrument permits the rapid collection of Raman signals from gases with short optical integration times, and thus real-time or near real-time measurement rates. This advancement in the instrument configuration enables greater benefit from the positive features of Raman. Firstly, all gas species except the noble gases exhibit Raman scattering signals. Each of these signals is intrinsically identifiable since the vibration or rotation of molecular bonds gives rise to specific Raman emissions of discrete energy. While solids and liquids exhibit continuous and broad energy transitions, those resulting from the excitation of gases are narrow and easily identified. Furthermore, the diatomic molecules all exhibit well defined and well separated Raman lines which can be used for their characterization. Lastly, systems operating in the visible region produce larger signals (Raman signal power increases as wavelength decreases via a 4th power relationship), and are well suited for recording with common CCD detectors or cameras. These features make spontaneous Raman an attractive method for gas analysis [3].

It should also be noted that methods of improvement have been developed to the spontaneous Raman process, but with the expense of additional measurement system complexity. Since the invention by C.V. Raman in the 1920’s, researchers have developed enhanced processes such as SERDS (shifted excitation Raman difference spectroscopy), along with coherent processes such as CARS (coherent anti-Stokes Raman spectroscopy) and SERS (surface enhanced Raman spectroscopy) [5]. There are a number of systems that utilize these technologies successfully for measurement, but the reasoning behind choosing an enhanced spontaneous method versus the others for gas measurement is simple. Each of the coherent processes introduces nonlinearity into the measurement, making quantification far more difficult. While processes like SERDS may retain linearity, it (as well as non-linear processes like CARS, etc) usually requires 2 lasers thus significantly complicating the measurement process [6]. While spontaneous Raman may not produce the largest signals, it does have simpler laser system requirements and permits linear analysis of Raman spectra to determine constituent composition.
Experimental Determination of Detection Limits

The methods used in the determination of the method detection limit (MDL) were taken from standard practices and modified to fit specifically for the Raman Gas Analyzer. Seven-minute samples (420 data points) were used for the MDL determinations, as seven aliquots were required in the MDL method defined in the Environmental Protection Agency document 40CFR1.136 [7]. The described method is valid for samples where individual tests produce only one value. Hence, modifications were necessary for more realistic and sufficient RGA data. The detailed methods used with the Raman Gas Analyzer are described in the following sections.

The MDL is the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero [7]. To begin, an expected MDL was estimated. The estimate was based on the blank data and graphs of the mole fraction percent of the species of interest against the signal-to-noise ratio. The percentage with a signal-to-noise ratio near three was used as the estimate.

A range of appropriate low-level samples at approximately three to five times the estimated MDL were mixed by calibrated mass flow controllers (MFCs) and supplied to the Raman Gas Analyzer. Data was taken for seven minutes, or 420 data points at 1 sample/second. The average, variance, and standard deviation of the results were calculated for each species of interest using a spreadsheet. The MDL is calculated as follows [7]:

\[
\text{MDL} = s \times t_{(n-1, 1-\alpha = 0.99)}
\]

where \(s\) is the standard deviation of the data and \(t\) is the Student’s t-value [7, 8] appropriate for a standard deviation estimate with \(n-1\) degrees of freedom and a 99% confidence level; in this case, \(t = 2.34\) (419 degrees of freedom, 99% confidence). The following inequality was used as a guideline to confirm that suitable spike levels (known test concentrations) were being tested.

\[
\text{Calculated MDL} < \text{Spike Level} < 5 \times \text{Calculated MDL}
\]

The experimental data were used to calculate the MDL. If the spike level used in the experiment fell outside these limits, a new spike level was selected to fit the projected limits, and the process was repeated. Once these conditions were met with a set of low-level measurements, a verification process using the F-ratio test was carried out. The F-ratio was calculated using the variances of two separate data sets, \(S_A^2\) and \(S_B^2\), both at inequality-fitting spike levels. The larger value is always used in the numerator: \(S_A^2/S_B^2\) must be less than 1.26, which is the critical F-value for 419 degrees of freedom and 99% confidence. The pooled standard deviation was calculated according to the following equation [7], which has been adjusted for the number of samples:

\[
S_{\text{pooled}} = \left[ \frac{420S_A^2 + 420S_B^2}{840} \right]^{1/2}
\]

where the coefficients are the number of data points in each set, and the denominator is the sum of the number of data points. The final MDL was computed in the same way as the initial MDLs using the new \(S_{\text{pooled}}\) value and a new t-value.
\[ MDL = (S_{pooled}) \times t_{(n-1, 1-\alpha = 0.99)} \]

Here \( t = 2.33 \) (more than 500 degrees of freedom, 99% confidence).

The results of the MDL testing for methane, hydrogen, and carbon monoxide are summarized in Table 1. As expected, the MDL varies with the gas species and the sample pressure. This is because spontaneous Raman scattering is linearly proportional to the density of the molecules of interest, and the Raman scattering cross section of the molecule [2]. The effect of the density on the resulting Raman scattering signal is readily seen in the MDL data, since as the pressure is increased (and therefore the density with fixed temperature and volume), the MDL decreases. The CH\(_4\) data fit the expected behavior especially well, where a near 3:1 inverse relationship was identified with increasing pressure.

Table 1. Method Detection Limit results.

<table>
<thead>
<tr>
<th></th>
<th>CH(_4)</th>
<th>H(_2)</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>20 psia</strong></td>
<td>0.046%</td>
<td>0.122%</td>
<td>0.418%</td>
</tr>
<tr>
<td><strong>60 psia</strong></td>
<td>0.014%</td>
<td>0.051%</td>
<td>0.121%</td>
</tr>
</tbody>
</table>

The values of the MDL were below 500 ppm for a few of the cases, and below 0.5% for all cases. Increasing the optical integration time could easily decrease the MDLs, for applications which could tolerate a slower readout of the concentrations. Increasing the sample pressure in the RGA is also a simple approach to decreasing the MDL. RGA data processing improvements are also being explored.

**Application to Chemical Looping**

Chemical looping combustion is being developed with support of the U.S. Department of Energy because it potentially will allow for carbon capture with better overall efficiency than conventional power cycles with post-combustion capture [9, 10]. Chemical looping uses an intermediary, such as a metal oxide, to collect oxygen from air in the air reactor. The oxidized particles are then transported to the fuel reactor, where the oxygen carrier particles are reduced. The product gas stream contains mostly carbon dioxide and water vapor, which can be readily separated for carbon capture, utilization and storage. An inert buffering gas is injected in the process between the reactors to help separate the oxidation and reduction processes. Proposed chemical-looping combustion systems have operating conditions which vary with the configuration and oxygen carrier, to pressures in excess of 20 atmospheres, and temperatures as high as 1050°C for iron-based carriers [11-14].

The Chemical Looping Reactor (CLR) has been designed and constructed at NETL for the purpose of research and development of the chemical looping [15-17]. The chemical looping reactor operates at high temperature (~ 1000°C) and is pressurized. The composition of gases produced by the fuel reactor is a key information for understanding the operating condition, and enabling control decisions to be made for the system. The CLR is presently fueled with natural gas, but additional nitrogen is...
used to improve fluidization of the oxygen carrier particles. In addition, during certain operations such as warmup, air may be supplied to the CLR for a preheat combustion mode with natural gas. As a result, the product gases from the fuel reactor include nitrogen, oxygen, carbon dioxide, carbon monoxide, water vapor, and unreacted methane. Hydrogen may also be produced under limited conditions. The Raman Gas Analyzer is well suited for monitoring this mixture of gases, although the low pressure available for gas analysis after gas clean-up to remove the particles limits the signal strength.

Data from a 12 hour period of the CLR test operations is shown in Figure 2, which plots carbon dioxide, methane, oxygen, and nitrogen concentration measurements from the fuel reactor. The RGA reports a gas composition every second during this period. The on-line gas chromatograph reports data every 2 minutes. Both show the response of the fuel reactor product gas composition to operational changes. Water vapor was detected by the RGA, but is not shown in the figure, because the sample gas clean-up system for included water removal with a 5°C (40°F) condenser. As a result, the measured water vapor was primarily a function of water vapor saturation at the condenser temperature, instead of the CLR process. The sample pressure after cleanup was about 5 psig.

Although the two measurements are not exactly the same, Figure 2 does show that both RGA reported compositions and GC reported measurements generally agree on the operating behavior of the CLR fuel reactor. The most noticeable difference is in carbon dioxide concentration. Its cause is being investigated, but is likely due to a combination of drift of the gas chromatograph, and low signal-to-noise on the RGA due to the low sample pressure. During transients, such as that shown in Figure 3, the much faster response of the RGA is valuable to the operators to understand the transient behavior which is occurring. This enables the operators to make smarter adjustments to the operation. The GC, in comparison, did not accurately capture all of the transient information recorded by the RGA.
Figure 2. Raman Gas Analyzer (lines) and online gas chromatograph (open symbols) data from the fuel reactor during CLR research operations at NETL.
Conclusions

The novel configuration of a reflectively lined capillary as a flow through sample cell and optical element has provided a large improvement in signal collection from gas phase Raman scattering, enabling the development of a new instrument with real-time gas analysis capability for major concentration species. NETL has performed the R&D to move this technology from the lab bench to a field application prototype. The method detection limits of a prototype for methane, hydrogen, and carbon monoxide were experimentally investigated, and found to be below 0.5% at 20 psia for all three species. The detection limits improve linearly with increased process pressure, which is beneficial for most industrial applications. Data from monitoring an experimental chemical looping reactor is also reported, demonstrating fast multi-species gas composition monitoring, which is particularly valuable for observation and control of transient events. Future plans include additional testing of the RGA in support of DOE research applications, support of technology transfer activities, and minor refinements to the field test units.

Figure 3. Raman Gas Analyzer (lines) and GC data (open symbols) from CLR operation, showing data during a rapid change.
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Patch Theory: Robustness/Performance Enhancement Of Power Plant PID Control Clusters Through Analytical Design

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KEYWORDS
Robustness, PID Controller, $H_{\infty}$ Control

ABSTRACT

In the previous work the *PID cluster robustification* has been carried out. It consisted in imparting some of the robustness/performance attainable by a full-order $H_{\infty}$ robust controller onto the existing power plant PID control clusters through compensating for the main structural and/or dynamic deficiencies of the PID-based designs. For this purpose, augmentation of the existing PID clusters with several static and/or dynamic *robustifying links* extracted from the full-order robust controller, without fully implementing the latter, has been proposed. To permit easy disabling of the additional control elements, if needed, they were run in parallel with the existing PID based controls. The high order of robustifying links has been reduced for implementing on the existing DCS control blocks. However, the robustifying links extraction procedure was heuristic and involved a very time consuming exhaustive search with no guarantee of the desired outcome. In this paper, a new methodology for the design of robustifying links, referred to as “patch theory” is introduced. The methodology proposed replaces the heuristic search with the consistent analytical design with guaranteed outcome. Simulation example is presented to show the efficacy of the new approach.
INTRODUCTION

Power plant control systems at present are, in large part, controlled by multi-input/multi-output clusters of the interconnected single-input/single-output PID controllers, termed here PID clusters. The latter, although possibly well-tuned and performing well for a given plant condition, have been known to exhibit the loss of controlled process performance under plant changes, such as those brought on by cycling, load following, fuel variations, and component wear and tear. Thus, to maintain good performance, these unit operation departures from a given design envelope call for frequent controller retuning even for a nominally gain-scheduled PID cluster.

To address the latter problem, a recent EPRI funded project [1], [2], has been carried out, where application of several local and global optimizers to simultaneous tuning of multi-loop PID cluster gains has been assessed. The local technique selected - iterative feedback tuning (IFT) - used the linearized version of the PID cluster for signal conditioning, but the data collection and tuning were carried out on the full nonlinear closed-loop system. The global techniques used (in the context of local tuning) were particle swarm optimization (PSO), simulated annealing (SA), and genetic algorithm (GA). They all provided the specified time domain responses through the appropriately chosen static and/or dynamic weighting of the individual terms in the performance index and could potentially automatically address the frequent retuning need.

During this research, a rigorous assessment of robustness, i.e. capability of controller to guarantee closed-loop stability and performance retention under changing plant characteristics, has been also carried out. Although it has been well understood that the need for retuning of PID clusters stems from their limited performance robustness, it has been assumed that the existing PID clusters guarantee reasonable gain and phase stability margins. However, it has been unexpectedly discovered that

1) the stability and performance robustness of the standard PID cluster structure is an order of magnitude lower than expected, being virtually absent at some frequencies, and that

2) PID cluster robustness is actually further degraded by the tuning based on time-domain performance specifications, meaning that the better the PID cluster is tuned, the more sensitive the closed loop performance to plant changes becomes.

These problems have brought out a dramatic demonstration of the fact that while tuning single PID loops for phase and gain margins could be carried out, doing this for the entire PID cluster, while also providing good time-domain performance, is virtually impossible, and is known to be an NP-hard (exponentially computationally difficult) problem. Thus, both of the above-indicated problems were assessed as clearly spelling potential disaster in the form of extreme performance loss, or closed loop stability loss under even not very significant changes in plant parameters.

Earlier research [3], [4] on the use of modern robust control strategies, such as $H_\infty$ [5], [6], [7], [8], in boiler/turbine control under EPRI and NSF support, showed significant benefits of these techniques. In a subsequent work [9], multivariable $H_\infty$ controller of the 2-input-2-output system was demonstrated to display performance robustness superior to that of the then-employed nonlinear PID controller [10]. Finally, [11] has designed a full operating range $H_\infty$ robust hybrid controller using bumpless transfer technique.
Even though controllers developed in these works have been shown to provide significantly better performance in terms of overshoot and settling time under changing plant conditions, clearly implying structural/dynamic deficiency of the exiting PID clusters, the use of these controllers has not been catching on in industry, since these methods, as a rule, require wholesale replacement of the existing PID type control logic with a high-order multivariable control system that is difficult for control staff to understand and maintain.

To address this dichotomy, an idea of the PID cluster robustification has been proposed – imparting some of the robustness/performance attainable by a full-order $H_\infty$ robust controller onto the existing power plant PID control clusters through alleviating the main structural and/or dynamic deficiencies of the PID-based designs. For this purpose, augmentation of the existing PID clusters with several static and/or dynamic robustifying links extracted from the full-order robust controller, without fully implementing the latter, has been proposed. The starting topology has been to run the existing PID based controls in parallel with the additional control elements, so that the latter could be easily disabled, permitting, if needed, a quick return to the original control configuration. To facilitate subsequent transitioning of the resulting technique to the power industry, the high order of robustifying links has been reduced to permit implementing the PID cluster enhancement by means of the existing DCS control blocks.

The effort has been carried out in two phases. The first phase [12] has explored robustification of a typical drum-based boiler/turbine system [13], [14]. Based on the clear demonstration of the PID cluster robustification for the latter system, the second phase has been undertaken [15], [16], with the support of EPRI and NSF, for a more difficult, once-through supercritical boiler/turbine system. The plant model used in the first phase has been put together as a generic drum-based boiler/turbine configuration. In the second phase, the once-through boiler/turbine model has been created that partially matched the dynamics of the nonlinear high fidelity plant simulator at the nominal load.

It has been found that these two types of boiler/turbine systems have vastly different dynamic characteristics. Namely, in the drum-based system, the PID cluster deficiency has been determined to be localized mainly in the low frequency range, whereas in the once-through system, the low frequency performance was robust, but the PID cluster deficiency was localized in the mid- to high frequency range.

The robustifying elements have been obtained for each system as follows. For the drum-based system, a Taylor series expansion about 0 with respect to the variable $s$ (the Maclaurin expansion), has been applied to a full-order controller, whereas for the once-through system, a controller order reduction based on balanced truncation, with subsequent link elimination based on exhaustive search, has been carried out.

The resulting robustifying links came out as follows:

1) for the drum-based system, a set of ten static gains has been extracted;
2) for the once-through system, two sets of robustifying links have been found, given, respectively, by two 3rd order and four 1st order transfer functions.

Applying the links to the respective PID clusters, a significant performance robustness improvement of each closed loop system has been attained. Namely, it has been computationally demonstrated in Simulink in both cases that the closed loop plant under the enhanced controller retains stability over a nontrivial set of plant perturbations for which the closed loop plant under the nominal controller goes unstable. The results of this effort have clearly demonstrated the potential
of the approach proposed. The visible robustness enhancement attained provides motivation to further pursue application of the approach proposed to the power plant control.

The work indicated above relied, however, on the ad hoc methods, including very time consuming exhaustive searches with no guarantee of finding robustifying links. The present paper proposes a consistent methodological analytical framework for PID cluster performance/robustness enhancement, referred here as “patch theory”, that is based on the following idea. References [12] and [15] show that the high-order \( H_\infty \) controller provides for a given operating point better time domain performance and significantly better performance robustness. This means that if a PID cluster were to match these properties, a topological and dynamic mismatch between the cluster and the robust controller should be removed. The latter could be accomplished by formulating the analytical difference between these controllers and reducing the complexity of this difference to allow its actual implementation. The paper presents analytical formulation of this approach, its application to a PID controlled boiler/turbine model, and demonstration of its efficacy through numerical examples.

### PLAN MODELING AND LINEARIZATION

The plant model used in this work is shown in Figure 1.[12] The model is incremental, describing dynamics of all deviation variables with respect to nominal operating condition and is designed to represent a 250 MW plant dynamics around 80% operating point. The nominal operating point values are specified as follows:

- **Megawatt Output** = 200 MW
- **Throttle Pressure** = 12.5 \( \times 10^6 \) Pa
- **Steam Flow Rate** = 80 %
- **Excess oxygen** = 3 %
- **Air Flow Rate** = 80 %
- **Drum Level** = 0 m
- **Feedwater Flow Rate** = 80 %

and all inputs are 80 %.

The process outputs in this model are:
- \( \Delta y_1 \) - MW, Unit Load (megawatts),
- \( \Delta y_2 \) - TP, Throttle Pressure (Pa),
- \( \Delta y_3 \) - SF, Steam Flow Rate (%),
- \( \Delta y_4 \) - O2, Excess oxygen (%),
- \( \Delta y_5 \) - AF, Air Flow Rate (%),
- \( \Delta y_6 \) - DL, Drum Level (m),
- \( \Delta y_7 \) - FW, Feedwater Flow Rate (%).

The control inputs to the process are:
- \( \Delta u_1 \) - TV, Turbine Valve Position (%),
- \( \Delta u_2 \) - FR, Firing Rate Demand (%),
- \( \Delta u_3 \) - FD, FD Fan Damper Demand (%),
- \( \Delta u_4 \) - FWV, Feedwater Valve Position Demand (%),
- \( k \) - Controller parameter vector.

The model is nonlinear. Deadtimes are included in the model, i.e. blocks “TV to MW3”, “FR to PT2” and “FR to FF2” to represent the time delays inherent in the processes, such as coal pulverizers dynamics. There are cross couplings in the model between several inputs and outputs. The turbine valve position affects both the power output and the throttle pressure as does the firing rate demand. The latter also affects the excess oxygen. The power output (steam flow rate) also affects the drum level. The control system structure used in the closed-loop simulation is that given

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in Figure 2. The nonlinearities of the control system arise from the lookup table, bias, and multiplication components as shown in Figure 2 [12]. Thus, the controller is given by the six-PID cluster that includes one lookup table and one multiplication operator and two biases, making the cluster nonlinear. This control system structure provides a simple but non-trivial testbed for the multi-loop tuning and $H_{\infty}$ design.

![Simulink Model](image)

**Fig. 1. Simplified process model schematic diagram in Simulink**
Fig. 2. SIMULINK representation of the nonlinear PID cluster

Although this model is nonlinear, the real process is almost always working in the vicinity of its operating point around which the linearized model is a good approximation of the nonlinear system. On the other hand, controllability and observability tests are easily applied to the linearized model, providing indication for the controllability and observability of the nonlinear system around operating point. The linearized system is obtained in the form of a 7x4 transfer function matrix given by:

\[
\begin{bmatrix}
MW \\
TP \\
SF \\
O2 \\
AF \\
DL \\
FW
\end{bmatrix}
= \begin{bmatrix}
H_{11}(s) & H_{12}(s) & 0 & 0 \\
H_{21}(s) & H_{22}(s) & 0 & 0 \\
H_{31}(s) & H_{32}(s) & 0 & 0 \\
0 & H_{42}(s) & H_{43}(s) & 0 \\
0 & 0 & H_{53}(s) & 0 \\
H_{61}(s) & H_{62}(s) & 0 & H_{64}(s) \\
0 & 0 & 0 & H_{74}(s)
\end{bmatrix}
\begin{bmatrix}
TV \\
FR \\
FD \\
FWV
\end{bmatrix}
\]

where

\[
H_{11}(s) = \frac{900s^5 - 9000s^4 + 4.05 \times 10^4 s^3 - 9.45 \times 10^4 s^2 + 9.45 \times 10^4 s}{2760s^6 + 2.784 \times 10^5 s^5 + 1.266 \times 10^5 s^4 + 3.007 \times 10^5 s^3 + 3.153 \times 10^5 s^2 + 2.551 \times 10^4 s + 105},
\]

\[
H_{12}(s) = \frac{0.0001454s^4 - 9.691 \times 10^{-5}s^3 + 2.907 \times 10^{-5}s^2 - 4.523 \times 10^{-6}s + 3.015 \times 10^{-7}}{s^5 + 0.6747s^4 + 0.2054s^3 + 0.03273s^2 + 0.00233s + 1.762 \times 10^{-5}s + 6.844 \times 10^{-8}},
\]

\[
H_{21}(s) = \frac{-3.677s^3 - 0.0352s - 0.001043}{5s^3 + 1.042s^2 + 0.008645s + 4.9 \times 10^{-5}}.
\]

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\[
H_{22}(s) = \frac{0.000603s^4 - 0.000402s^3 + 0.0001206s^2 - 1.876 \times 10^{-5}s + 1.251 \times 10^{-6}}{s^6 + 0.6747s^5 + 0.2054s^4 + 0.03273s^3 + 0.00233s^2 + 1.762 \times 10^{-5}s + 6.844 \times 10^{-8}},
\]
\[
H_{31}(s) = \frac{180s^5 - 1800s^4 - 1.89 \times 10^4s^2 + 1.89 \times 10^4s}{2760s^8 + 2.784 \times 10^4s^5 + 1.266 \times 10^5s^4 + 3.007 \times 10^5s^3 + 3.153 \times 10^5s^2 + 2.551 \times 10^4s + 105},
\]
\[
H_{32}(s) = \frac{2.907 \times 10^{-5}s^4 - 1.938 \times 10^{-5}s^3 + 5.815 \times 10^{-6}s^2 - 9.045 \times 10^{-7}s + 6.03 \times 10^{-8}}{s^6 + 0.6747s^5 + 0.2054s^4 + 0.03273s^3 + 0.00233s^2 + 1.762 \times 10^{-5}s + 6.844 \times 10^{-8}},
\]
\[
H_{42}(s) = \frac{-0.008151s^4 + 0.005434s^3 - 0.00163s^2 + 0.0002536s - 1.691 \times 10^{-5}}{25s^8 + 226.5s^7 + 226.7s^6 + 105.6s^5 + 28.51s^4 + 4.664s^3 + 0.4349s^2 + 0.01827s + 6.762 \times 10^{-5}},
\]
\[
H_{43}(s) = \frac{0.25}{3600s^4 + 2040s^3 + 409s^2 + 34s + 1},
\]
\[
H_{53}(s) = \frac{1}{144s^2 + 24s + 1},
\]
\[
H_{61}(s) = \frac{31.5s^6 - 317.7s^5 + 1445s^4 - 3429s^3 + 3591s^2 - 283.5s}{4.347 \times 10^6s^{10} + 4.505 \times 10^7s^9 + 2.116 \times 10^8s^8 + 5.297 \times 10^9s^7 + 6.32 \times 10^{10}s^6 + 1.886 \times 10^8s^5 + 2.323 \times 10^7s^4 + 1.305 \times 10^6s^3 + 2.94 \times 10^4s^2 + 105s},
\]
\[
H_{62}(s) = \frac{-2.455 \times 10^7s^5 - 3.828 \times 10^6s^4 + 1.308 \times 10^6s^3}{1575s^{10} + 1498s^9 + 653.9s^8 + 166.9s^7 + 26.18s^6 + 2.458s^5 + 0.1267s^4 + 0.003011s^3 + 2.015 \times 10^{-5}s^2 + 6.844 \times 10^{-8}s},
\]
\[
H_{64}(s) = \frac{-0.0875s + 0.0075}{945s^3 + 828s^2 + 246s^3 + 28s^2 + s},
\]
\[
H_{74}(s) = \frac{0.5}{9s^2 + 6s + 1},
\]

The linearized system transfer function matrix given above can be represented by LTI state space system

\[
\dot{x}(t) = Ax(t) + Bu(t),
\]
\[
y(t) = Cx(t),
\]

where \( x(t) \) is the state vector, \( u(t) \) is the input vector, and \( y(t) \) is the output vector; and \( A, B, C \) are real matrices. We define the dimensions of the vectors as \( u(t) \in R^m, \ x(t) \in R^n, \) and \( y(t) \in R^p \).

Thus matrices \( A, B, \) and \( C \) are \( n \times n, \ n \times m, \) and \( p \times n, \) respectively. The state space realization of the transfer function matrix yields \( n = 52 \) states, \( m = 4 \) inputs, and \( p = 7 \) outputs, so that \( A \) is \( 52 \times 52, \) \( B \) is \( 52 \times 4 \) and \( C \) is \( 7 \times 52 \). Matlab routines “ctrfb” and “obsvf” are used to calculate controllability and observability staircase forms of the system as well as the number of controllable
and observable states. It yields 52 controllable and 52 observable states, although it is essentially a $4 \times 4$ system since only four out of seven outputs need to track the setpoint changes.

**PATCH THEORY: ANALYTICAL DESIGN OF THE PID CONTROL CLUSTER MODIFICATIONS**

The analytical design of the cluster modifications can be formulated as follows.

Let the closed loop with plant $P$ under PID cluster $K_{PID}$ be represented by a multi-input/multi-output operator $\mathcal{F}_1(P, K_{PID})$, so that the relation between the exogenous inputs $w$, such as reference signal, and performance outputs $z$, such as output tracking error be given by

$$z = \mathcal{F}_1(P, K_{PID})w$$

Let the closed loop with plant $P$ under $H_\infty$ controller $K_H$ be represented by a multi-input/multi-output operator $\mathcal{F}_2(P, K_H)$, so that the relation between the exogenous inputs $w$ and performance outputs $z$ be given by

$$z = \mathcal{F}_2(P, K_H)w.$$  

Introduce a closed loop $H_\infty$/PID mismatch as

$$z = [\mathcal{F}_2(P, K_H) - \mathcal{F}_1(P, K_{PID})]w =: \mathcal{F}_3(P, K_{PATCH})w,$$

where the $K_{PATCH}$ is the controller, referred to as patch, that provides closed loop mismatch realization.

Then, assuming the same input/output configuration for PID cluster and $H_\infty$ controller,

$$K_{PATCH} = K_H - K_{PID}.$$  

If fully implemented, $K_{PATCH}$ would completely cancel out PID cluster dynamics and replace it with $H_\infty$ controller $K_H$, which is clearly impractical. For this reason, and also since $K_{PATCH}$ will have the order equal to the sum of the orders of $K_H$ and $K_{PID}$, it has to be reduced for implementation, with its key features extracted. Once the latter is carried out, the resulting patch $\bar{K}_{PATCH}$ will be combined in parallel with $K_{PID}$ to yield

$$\bar{K}_{PATCH} + K_{PID} \approx K_H.$$  

For PID cluster with nonlinearities, $\bar{K}_{PATCH}$ should be modified to accommodate the latter. To cover the entire operating range, a multipatch consisting of several patches based on $H_\infty$ controller designs at several key points could be employed in a hybrid (switching) fashion.

**CASE STUDY**
Based on the closed-loop system in [12], we design two different robustified IFT-tuned PID cluster controllers.

**DESIGN 1: PID CLUSTER PATCHING – EXTRACT ROBUSTIFYING LINKS FROM THE DIFFERENCE BETWEEN LINEARIZED PID CLUSTER AND A THIRD-ORDER $H_\infty$ CONTROLLER**

The linearized PID cluster of the nonlinear PID cluster in [12] is as follows:

The PID cluster is simplified by eliminating the nonlinear components, i.e. deleting the lookup table and two bias blocks and replacing the multiplication operation by summation. We indexed the 6 different PIDs from top to bottom as 1 to 6. Therefore PID1 is the MW controller, PID2 is the Throttle Pressure controller, PID3 is the Air Flow Rate controller, PID4 is the Excess Oxygen controller, PID5 is the Drum Level controller, and PID6 is the Feedwater Flow Rate controller. Then the simplified linear controller is shown in Figure 3:

\[
e = r - y \quad \begin{array}{c}
\left[ u_1 \\
\left[ u_2 \\
\left[ u_3 \\
\left[ u_4 \\
\left[ u_5 \\
\left[ u_6 \\
\left[ u_7 \\
\end{array}
\end{array}
\quad \begin{array}{c}
C(k) \\
\end{array}
\quad \begin{array}{c}
\left[ r_1 - y_1 \\
r_2 - y_2 \\
r_3 - y_3 \\
r_4 - y_4 \\
r_5 - y_5 \\
r_6 - y_6 \\
r_7 - y_7 \\
\end{array}
\end{array}
\]
\end{array}
\]

**Figure 3. A simplified linear PID controller representation**

In Figure 3, we have the following definitions.

\[
u = \begin{bmatrix}
u_1 \\
u_2 \\
u_3 \\
u_4 \\
u_5 \\
u_6 \\
u_7 \\
\end{bmatrix}, \quad e = r - y = \begin{bmatrix}
r_1 - y_1 \\
r_2 - y_2 \\
r_3 - y_3 \\
r_4 - y_4 \\
r_5 - y_5 \\
r_6 - y_6 \\
r_7 - y_7 \\
\end{bmatrix},
\]

\[
u = \begin{bmatrix}
PID_1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & PID_2 & -1 & 0 & 0 & 0 & 0 \\
0 & PID_2 \times PID_3 & -PID_3 & PID_4 \times PID_3 & PID_3 & 0 & 0 \\
0 & 0 & -PID_6 & 0 & PID_5 \times PID_6 & PID_6 & PID_6 \\
\end{bmatrix}.
\]

We denote the three gains in each PID as $k_{ij}, i = 1,2,\cdots, 6,$ $j = 1,2,3,$ where $i$ represents the PID number and $j$ represents the corresponding proportional, integral and differential gains. Each PID has continuous system representation as follow:

\[
PID_i = k_{i1} + \frac{k_{i2}}{s} + k_{i3}s
\]

We design a full-order $H_\infty$ controller first and then derive a reduced-order one for implementation. The derived third-order $H_\infty$ controller is:

\[
C_{H_{3rd}} = [f_{ij}(s)] \quad i = 1,2,3,4; j = 1,2,\cdots, 7.
\]
The $H_\infty$/PID mismatch is:

$$C_{ks} = C(k) - C_{H3rd} = [g_{ij}(s)], \quad i = 1,2,3,4; \ j = 1,2,\cdots,7. \quad (5)$$

We extract three robustifying links $g_{11}(s)$, $g_{21}(s)$, and $g_{41}(s)$ from $C_{ks}$ and augment the original nonlinear PID cluster controller in parallel with these links, as shown in Figure 4.

$$g_{11}(s) = \frac{2.374s^4 + 0.09591s^3 + 7.034 \times 10^{-6}s^2 + 1.166 \times 10^{-10}s + 2.164 \times 10^{-16}}{s^4 + 7.277 \times 10^{-5}s^3 + 1.183 \times 10^{-9}s^2 + 2.192 \times 10^{-15}s}$$

$$g_{21}(s) = \frac{0.6334s^3 - 0.00336s^2 - 1.733 \times 10^{-7}s - 1.867 \times 10^{-13}}{s^3 + 7.277 \times 10^{-5}s^2 + 1.183 \times 10^{-9}s + 2.192 \times 10^{-15}}$$

$$g_{41}(s) = \frac{2.613s^3 - 0.005836s^2 - 2.983 \times 10^{-7}s - 1.547 \times 10^{-15}}{s^3 + 7.277 \times 10^{-5}s^2 + 1.183 \times 10^{-9}s + 2.192 \times 10^{-15}} \quad (6)$$

Figure 4. Structure of PID cluster augmented by $H_\infty$/PID mismatch

**DESIGN 2: HEURISTIC EXTRACTION OF ROBUSTIFYING LINKS FROM A THIRD-ORDER $H_\infty$ CONTROLLER**

Now we use the PID control cluster augmentation design method of [15] and design a robustified IFT-tuned PID cluster controller. The dynamic robustifying link works in parallel with the existing
PID cluster as shown in Figure 5, passing EO Error to FD Fan Damper Demand through a 3rd order transfer function.

The robustifying link, which is in the form of a 3rd order transfer function, as well as the tuning knobs of weighting matrixes $W_k$ and $W_{ks}$ are given in Table 1 for the original process model under dynamic changes.

**Table 1 Robustifying Link and Tuning Knobs for Process Model under Dynamic Change**

<table>
<thead>
<tr>
<th>Process model under dynamic change</th>
<th>Robustifying Link</th>
<th>Tuning Knobs</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{43}(s) = \frac{10.4495s^3 + 0.36642s^2 + 8.3399 \times 10^{-6}s + 1.6055 \times 10^{-11}}{s^3 + 7.2774 \times 10^{-5}s^2 + 1.1825 \times 10^{-9}s + 2.0 \times 10^{-15}}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$W_k = diag\left(\frac{6}{5s + 0.0001}, \frac{100}{s + 0.004}, 0, \frac{8}{2s + 0.0001}, 0, \frac{15}{s + 0.3}, 0\right)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$W_{ks} = diag(5, 5, 1, 1)$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 6 compares the Bode plots of the singular values of the closed-loop systems for the robustified IFT-tuned PID cluster design 1 by augmenting the original one with closed loop $H_{\omega}/PID$ mismatch in this section, the robustified IFT-tuned PID cluster design 2 with augmentation method in [15], the original IFT-tuned PID cluster control systems with PID gains.
and the third-order $H_\infty$ controller. It can been seen from Figure 6 that both robustified PID controllers roll off to reject high-frequency noise signals sharply and respond to lower-frequency load disturbances and setpoints. The closed-loop system with the robustified PID controller shows considerable improvements in overall robustness when compared to that with the IFT tuned PID cluster, especially in the mid-to-high frequency range.

The graphs also clearly show the difference between heuristic robustification and analytical robustification. While the peaks of the analytically robustified (green) and heuristically robustified (orange) closed loops are about the same, the latter is seen to be characterized by the lower values of the graph, and hence better robustness, in the low frequency range, whereas the former gives a better robustness in the low-to-mid-frequency range around $10^2$ rad/s where heuristic method produces a spike.

The asymptotic frequency domain properties of the closed loop for all controllers are fully visible above $10^2$ rad/sec.

Figure 6. Bode plots of the full set of the closed-loop singular values for IFT-tuned PID (CLPd) design, robustified IFT-tuned PID (CLPds) design 1, robustified IFT-tuned PID (CLPdhf) design 2, and third-order $H_\infty$ robust controller (CLhf) design

$k_{11} = 0.7853, k_{12} = 0.0987, k_{21} = 0.3642, k_{22} = 0.00001, k_{23} = 10.6147, k_{31} = 1.5766, k_{32} = 0.0739, k_{41} = 1.4767, k_{42} = 0.2126, k_{51} = 0.6889, k_{52} = 0.00009917, k_{61} = 17.4811, k_{62} = 0.3845$
SIMULATION RESULTS

In this section, the performance of the robustified IFT-tuned PID controller is evaluated. Both robustified IFT-tuned PID controller are applied to the original nonlinear boiler/turbine model under dynamic changes to see the time domain performance of the closed-loop system under 2%/min ramp changes in load demand setpoint. The control objective is to track the dispatched load demand while maintaining throttle pressure, excess oxygen, and drum level under modeling uncertainty.

Figure 7 compares the tracking performances of the original IFT-tuned PID cluster, the robustified IFT-tuned PID cluster using the results of the previous section and the third-order $H_\infty$ control system under the same reference signals, showing good performance of all closed loops with the nonlinear model, while the robustified PID cluster is performing better than the original one for maintaining most outputs. Figure 8 compares the tracking performances of the original IFT-tuned PID cluster, the IFT-tuned PID cluster robustified with methods of [15], and the third-order $H_\infty$ control system under the same reference signals, showing good performance of all closed loops with the nonlinear model, with the robustified PID cluster performing better than the original one.

The third-order $H$-inf controller has tracking performance loss due to drastic controller order reduction and the resulting large approximation error.
Figure 7. Comparison of the output responses generated by the original IFT-tuned PID (CLPd) cluster, the robustified IFT-tuned PID (CLPds) design 1 and third-order $H_\infty$ robust controller (CLhf) under model dynamic change with 2%/min load ramping increase. The units are: megawatts for $y_1$, psi for $y_2$, % for $y_4$, and inches for $y_6$.

The above results demonstrate that the robustified PID cluster with additional dynamic elements achieves much better robustness than the original PID cluster with improved tracking performance. The first design in this section that extracts robustifying links from the $H_\infty$/PID mismatch provides a performance/robustness enhancement comparable to the second one that extracts links heuristically from the $H_\infty$ controller through trial-and-error.

CONCLUSION

The present work shows that, while typical PID control clusters on power boilers/turbine units exhibit poor robustness, the latter can be “patched” by making simple modifications to the cluster.
The analytical approach to robustification, referred to as “patch theory,” is proposed, tying the robustification links synthesis to the closed loop system dynamics, and the existing controller topology and characteristics. Future work will focus on fully developing analytical approach and applying it to a range of the boiler/turbine systems.

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ISA Power Industry Division

Executive Committee Update

The ISA Power Industry Division (also known as POWID) is organized within the Industry and Sciences (I&S) Department of ISA to provide a means for information exchange among engineers, scientists, technicians, and management involved in the use of instrumentation and control in the production of electrical power by any means including but not limited to fossil and nuclear fuels. The POWID Executive Committee (EXCOM) administers the activities of the division. The Executive Committee normally meets face-to-face once a year at the POWID Annual Symposium in June and conducts conference calls/web meetings as needed throughout the year. POWID Executive Committee meeting minutes are available on the ISA POWID website at: https://www.isa.org/division/powid/leadership/. You must be a POWID member to view these minutes.
By Bob Queenan, Scientech, ISA67 Committee Chair

ISA67, the Nuclear Standards group of ISA, develops standards for instrumentation and controls and maintains, clarifies, updates, and provides application guidance on the standards already produced. ISA67 is organized to be the focal point in ISA for documenting through standards publications: criteria, standards, practices, and procedures related to instrumentation and controls in nuclear power generating stations and associated industries.

The committee met during POWID 2016 will a voting quorum present. We recognized the contributions that Pete VandeVisse has made over many years of participation; we’ll miss his active involvement as he starts into retirement. Several active subcommittees reported:

- Bill Barasa’s 67.01 subcommittee reports that ISA-67.01.01-2002 (R2007), Transducer and Transmitter Installation for Nuclear Safety Applications is in revision, with a full committee vote targeted for October.
- Klemme Herman’s 67.02 recently issued ISA-67.02.01-2014, Nuclear Safety-Related Instrument Sensing Line Piping and Tubing Standard for Use in Nuclear Power Plants and is slowly collecting information to support the next revision.
- Wayne Marquino has taken over leadership of 67.04 following Pete’s retirement. The group agreed to move ahead to revise or reaffirm ANSI/ISA-67.04.01-2006 (R2011), Setpoints for Nuclear Safety-Related Instrumentation. No changes are pending for ISA-RP67.04.02-2010, Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation.
- Brent Shumaker’s 67.06 is working to send a revision of ISA-67.06.01-2002, Performance Monitoring for Nuclear Safety-Related Instrument Channels in Nuclear Power Plants to the committee for vote by the end of the year.

The committee also looking for folks interested in developing guidance in the following areas:
- How cross-calibration should be addressed when calculating instrument uncertainty
- How normalization should be addressed when calculating instrument uncertainty
- What actions to take with the results of As-Found and As-Left data.
- What are acceptable methods for surveillance testing
- Moving forward into risk-informed uncertainty calculations

It’s an exciting time in nuclear, with new plants overseas, SMRs gaining acceptance, and constant challenges to keep the existing fleet working safely, efficiently, and productively. SP67 welcomes all who are interested in the future of instrumentation systems in nuclear power plants to come and join us in shaping the future. More information about the ISA67 Committee and its activities can be found at the ISA67 Committee website.

ISA77 Fossil Power Plant Standards Committee Update

By: Bob Hubby and Daniel Lee, Co-Chairs, ISA77 Committee

The ISA77 committee met June 27, 2016 as a part of the 2016 Symposium. The following are unofficial minutes from that meeting. For more information about ISA77, please visit the ISA77 committee website.

Attendees:

Members
- Daniel Lee (Co-Chair)
- Bob Hubby (Co-Chair—via WebEx)
- Gary Cohee
- Mike Cushing (via WebEx)
- Jody Damron
- Paul Hollingshead
- Henrik Johansen
- Xinshend Lou

Guests
- Mukesh Pandya
- Cyrus Taft
- Zeke Zadiraka (via WebEx)
- Eliana Brazda, ISA Staff
- Dale Evely
- Don Parker
- Zixue Lue

1. Call to Order
The ISA77 Fossil Fuel Power Plant standards committee meeting was called to order at 3:03 p.m. EST by ISA77 Co-Chair, Dan Lee.

2. Introduction of Attendees
Members both physically present and those attending via WebEx announced themselves. Dan reported that the ISA 77 Attendance list and ISA 77 roster are being distributed for members to sign and to update their contact information. If any member who is present via WebEx needs to update their contact information then, please contact Eliana with new contact information

3. Review & Approve Agenda
The ISA77 Committee meeting agenda was previously distributed with the meeting announcements. Dan asked if there were any other comments or corrections to the agenda. With no changes, Bob motioned to approve the agenda. Henrik seconded the motion. Nobody decline the motion so the agenda was approved as written.

4. Review & Approve Minutes of Last Meeting
The February 10, 2016 ISA77 committee meeting minutes were distributed electronically along with an approval ballot. With no comments, the minutes were approved electronically. The February 10th meeting minutes are available on the ISA77 committee web site.

5. Co-Chair Opening Remarks
Dan welcomed all ISA77 members to the physical and WebEx meeting and thanked everyone for their attendance. After the February ISA77 meeting, sub-committees continue to revise and ballot reaffirmed documents and to draft new documents. The purpose of this meeting is to review the status of documents in draft, in revision cycle, or in reaffirmation cycle.

Dan noted two issues on the ballot’s comment form that needs to be addressed. First, there has been several cycle of documentballoting as new technical comments are being submitted with each ballot. While the committee appreciated the time and effort to improve the document, the constant revision cycle is delaying the ability to complete the document revision. Please note that NFPA only has one public comment cycle for new comments and one public review cycle to comment on the committee resolution for the public comments. Thus, no new
public comments are accepted for this revision cycle. I would like to enforce this practice on the ISA 77 document cycle. As such, additional instructions will be provided to the review cycle ballot to ask that only the sections of the document change based on the comment form be balloted.

The second issue is when commenter's does not provide a proposed change in the comment form? While in principle the commenter's comment may be valid, the commenter is not being specific as to the requested change to the document. In the Standards Procedures, this is only addressed in regard to comments without proposed changes with a negative ballot, in 5.2.7 f):

Comments with negative ballots that are determined to be (1) unrelated to the item being balloted or (2) negative ballots submitted without comments, shall not be considered further and will be recorded as “negatives without comments“ for purposes of reporting to ANSI with no further notice to the submitter. In the first case, the commenter should be referred to the New Standards Project Proposal form available on the ISA web site for possible submission of a new proposal for consideration by the Board.

Please note this procedure is also used by the NFPA committee to allow the committee to reject a comment with no proposed change. Per ISA, procedures, if the commenter had approved the ballot and provided a comment with no proposal changes, then the committee chair will take this comment under consideration for the next revision cycle.

At the February meeting, a few new ISA 77 members were introduced. While there are no new members to introduce at this time, I ask that ISA 77 members continue to solicit new members for the committee. Dan’s previous email (06/25) notifying the committee of a change in ISA 77.20 co-chair position. Zeke has stepped down as co-chair and Alex Lekich had solicited and nominated Bruce Kelly as the new co-chair. Bruce’s resume was distributed via email. Dan reported that Alex Lekich is planning on having Bruce assume the chair duties but want a transition period for the first few meeting. Since Alex was not in attendance, Dan nominated Bruce as co-chair of ISA 77.20.01 and Cyrus second the motion. The members approved Bruce’s nomination.

Managing Director Opening Remarks
Joe Weiss was not present and no report was submitted. The S&P Board last met during the ISA Leaders Meeting in Raleigh, North Carolina on June 11-13, 2016. Dan has not received the June S&P Board meeting minutes.

I am pleased to report that Dr. Xinsheng Lou has been elected by the ISA Executive Board to become ISA Fellows. This is an honor that is hard-earned and requires a rigorous evaluation upon nomination. His work is focused on first principle dynamic modeling, advanced control design and optimization of steam generation and environmental controls for emerging clean coal and conventional power plants. Award presentations will be made at the 54th Honors and Awards Gala, on 24 September 2016 at the Newport Beach Marriott Hotel & Spa, Newport Beach, California, USA.

7. ISA77 Active Subcommittee Reports

<table>
<thead>
<tr>
<th>Committee</th>
<th>Published Date</th>
<th>Status - (EPR Date)</th>
<th>Chair Report</th>
</tr>
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<tbody>
<tr>
<td>ISA 77.00 General</td>
<td></td>
<td></td>
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<tr>
<td>ISA77.00.01 Definitions and Design Consideration</td>
<td>New report</td>
<td>Bill Hocking was not present. Dan reported that the committee’s held a WebEx on January 7 and on February 18 to review author assignment. The committee met today (June 27) to review new author assignments. New author assignments were made and the committee plans on hold another WebEx meeting on July 27 at 11:00. Dan reported that the committee is making good progress on the Design Consideration section and that a committee ballot is likely later this year.</td>
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| ISA77.10 Turbine Series |
| ISA77.13 Turbine Steam Bypass Systems | 2008 | In revision cycle | Dan has been unsuccessful in a search for a new committee chair. Dan will proceed as the interim chair to complete this document revision cycle. The document was balloted in 2013 but no work has been done to resolve the outstanding comments. |
| ISA77.14.01 Steam Turbine Controls | 2010 | In Reaffirmation cycle | Dan has been unsuccessful in a search for a new committee chair. Dan will proceed as the interim chair to complete this document revision cycle. The document was balloted in 2014 but no work has been done to resolve the outstanding comments. |

<p>| ISA77.20 Plant-wide Series |
| ISA77.20.01 Fossil Power Plant Simulators | 2012 | Current Standard | Alex was not present. Dan reported that the reaffirmation ballot was sent on May 17 and closed on June 16. The document was approved but several comments were received. The simulator committee plans on meeting in the future to resolve the comments. |
| ISA77.22.01 Power Plant Automation | New Standard (2015 Q4) | Henrik was present and reported that the ISA77.22.01 committee held a web meeting on March 2 and a physical meeting this morning today (June 27) to address author assignments. The document progress has been slow as author have not been submitting new material. Plan is to continue to solicit committee review and text in order to complete this document. |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>ISA77.30 Plant Performance Series</strong></td>
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<tr>
<td><strong>ISA77.40 Boiler Series</strong></td>
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<tr>
<td>TR77.40.01 Functional Diagramming</td>
<td>2012</td>
<td>Current Standard</td>
<td>Dan was present and reported that this document was balloted in March 7, 2016 and approved with comments on April 15. The committee met today (June 27) and resolved the comments. Dan will update the document and meeting minutes. Dan will confirm with Eliana if the comment response complete the reaffirmation process.</td>
</tr>
<tr>
<td>ISA77.41.01 Boiler Combustion Controls</td>
<td>2015</td>
<td>Current Standard</td>
<td>Report not required.</td>
</tr>
<tr>
<td>ISA77.42.01 Feedwater Control – Drum Type</td>
<td>2011</td>
<td>In Revision cycle</td>
<td>Paul Toigo/Jerry Gilman was presented. The committee met today (June 27) to review new content for once-through feedwater control. A few author assignments were made and the committee agreed to hold another WebEx meeting to review the final new material. The committee feels this document will be issue for ballot later this year.</td>
</tr>
<tr>
<td>ISA77.43.01 Unit Plant Demand Development</td>
<td>2014</td>
<td>Current Standard</td>
<td>Report not required.</td>
</tr>
<tr>
<td>ISA77.44.01 Steam Temperature Controls</td>
<td>2013</td>
<td>Current Standard</td>
<td>Report not required.</td>
</tr>
<tr>
<td><strong>ISA77.60 HMI Series</strong></td>
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<tr>
<td>ISA77.60.02 HMI: Hard Panel Alarms</td>
<td>2014</td>
<td>Current Recommended Practice</td>
<td>Report not required.</td>
</tr>
<tr>
<td>RP77.60.05 HMI: Task Analysis</td>
<td>2012</td>
<td>Current Recommended Practice</td>
<td>Bob was present and reported the document has completed its reaffirmation cycle and has been submitted for S&amp;P Board approval. There were a few editorial comments that were incorporated into the final revision.</td>
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<tr>
<td><strong>ISA77.70 Instrument Series</strong></td>
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<tr>
<td>TR77.70.01 Tracking and Controlling Instrument Documentation in Fossil Power Plants</td>
<td>2015</td>
<td>Current Technical Report</td>
<td>Report not required</td>
</tr>
<tr>
<td>ISA77.70.02 Instrument Piping Standards</td>
<td>2014</td>
<td>Current Standard</td>
<td>Report not required.</td>
</tr>
<tr>
<td>ISA 77.70.03 Integrating Calibration Management with Asset Management</td>
<td>New report</td>
<td>Jody was present and reported that the committee met for the first time this morning (June 27) to review the scope and outline of the new document. Content for the document will be prepared and distributed to the sub-committee for their review. A future WebEx meeting will be called to discuss the content.</td>
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<tr>
<td><strong>ISA77.80 Post Combustion Series</strong></td>
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<td></td>
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<tr>
<td>ISA77.82.01 SCR Instrumentation and Controls Standard</td>
<td>2011</td>
<td>In reaffirmation cycle</td>
<td>Cyrus was present and reported that document had received additional comments from the last ISA 77 ballot. The sub-committee held a WebEx meeting on June 16 to resolve committee comments. Cyrus will update the draft document and reissue the document for ISA 77 ballot with ballot instructions that committee member are to ballot on the comments resolution only.</td>
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8. **Liaison Reports**

**NFPA 85** – Dan Lee reported that the NFPA 85 2015 Edition has been published and is available via soft or hard copy. The NFPA 85 MBB committee plans met on March 16 as a pre-cycle review meeting to review progress of several committee task groups. Dates for the next revision cycle have not be published but the expected dates are:
- Public Input Closes Jan 2017
- Technical Committees Meet March 2017
- 1st Draft Sept 2017
- Public Comment Oct 2017
- Technical Committees Jan 2018
- Correlating Committee May 2018
- 2nd Draft July 2018
- Accepted Oct 2018

**ISA101** – Bob Hubby was present and report that for 2016 three new working groups have been approved and are starting to draft new technical reports. The three new working groups include;

**Working Group 1** is chartered to develop technical report(s) to support the HMI Philosophy and Style Guide System Standards lifecycle activities as described in clauses 4.2.1 and 4.2.2 of the standard, which define the guiding principles and conceptual foundation for the HMI design, as well as the Design Process described in clause 4.3 of the standard.

This technical report will describe example applications of the Philosophy and Style Guide to various Process Automation Systems use cases, and will be platform independent.

**Working Group 2** is chartered to develop technical report(s) to support the Human Factors engineering and ergonomics as described in clause 5 of the standard, and HMI Performance as described in clause 8 of the standard. This technical report(s) will be used to assess the effectiveness of the HMI application, and how use of the standard may assist in improving related metrics.

**Working Group 3** is chartered to develop technical report(s) to evaluate and define the use of mobile devices as HMI stations and how to effectively implement an HMI for use on a mobile device.

**VGB** - Henrik Johansen was present and had no news to report.

9. **Old Business**

   a) Solicit New ISA 77 Members: Dan reminded members to solicit new ISA 77 members.

10. **New Business**

    a) **ISA Fall Meeting:** Dan reported that the ISA Fall meeting is scheduled for September 24-27, 2016 at Newport Beach Marriott in Newport Beach, California.

    b) **New Member:** Cyrus noted that Dale Evely was interested in becoming a voting member of ISA 77. It was noted that Mukesh Pandya is already an information member. Mukesh agreed to be an alternative voting member to Dale. Thus, Gary made a motion to approve Dale as a voting member of ISA 77 and Mukesh as an alternative voting member. Paul second and the motion passed.

    c) **Other Topics:** Dan opened the meeting to any other topic the members wish to discussion. No additional topics were introduced.

11. **Time & Date of Next Meeting**

    Dan reported that the next ISA77 committee meeting is tentatively schedule as a WebEx meeting on October 5 at 11:00 a.m. EST. In the meantime, Dan encourages the subcommittee chairs to hold WebEx meetings to resolve committee comments.

12. **Adjournment**

    Dan asked for a motion to adjourn the ISA77 committee meeting. Cyrus made the motion and Bob seconded the motion. Nobody decline the motion so the ISA77 committee meeting was adjourned at 3:45 p.m.