Power Industry Division Newsletter

What's Watt

In This Issue:

Spring 2016

Director's Message

By Aaron Hussey

As 2016 is well underway, consider the opportunities that are available to you through ISA's Power Industry Division (POWID). Firstly, contributions to newsletters like this are always welcome. If you have a technical article, interesting find, or book description, please let the newsletter editor, Dale Evely, know. Secondly, ISA67 Nuclear Power Plant Standards and ISA77 Fossil Power Plant Standards committees have several subcommittees that are drafting new standards. Thirdly, the 59th Annual POWID/EPRI Controls & Instrumentation Symposium will be held from June 27th to June 30th, 2016 in Charlotte, North Carolina. Please mark your calendar and plan on joining us there.

The Spring 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 are 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.

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

POWER INDUSTRY DIVISION OFFICERS

DIRECTOR
Aaron Hussey
Expert Microsystems
ahussey@expmicrosys.com

DIRECTOR-ELECT
Xinsheng Lou
GE Power
xinsheng.lou@ge.com

NEWSLETTER EDITOR
Dale Evely
Southern Company
P.O. Box 2625 / Bin B463
Birmingham, AL 35202
(205) 992-6649
dpevely@southernco.com

Upcoming POWID and ISA Events

59th Annual ISA POWID Symposium
27-30 June 2016
Electronic Power Research Institute (EPRI) Conference Center
1300 West W. T. Harris Blvd.
Charlotte, North Carolina, USA
For more information visit www.isa.org/powid2016/

ISA Birmingham Section/Auburn University
46th Annual Fundamentals of Industrial Automation, Instrumentation, and Control Short Course
3-5 May 2016
Revere Control Systems
2240 Rocky Ridge Road, Birmingham AL, USA
For more information visit https://register.uce.auburn.edu/CourseStatus.awp?&course=C160503isa

You can find information on other ISA Events at www.isa.org/events

2016 POWID SYMPOSIUM COMMITTEE

GENERAL CHAIR
Susan Maley
Electric Power Research Institute (EPRI)
smaley@epri.com

PROGRAM CHAIR
Seth Olson
Chevron Power and Energy Management
seth.olson@chevron.com

PROGRAM CO-CHAIR, NUCLEAR
Chad Kiger
AMS Corporation
chad@ams-corp.com

PROGRAM CO-CHAIR, EMERGING TECHNOLOGIES
Sydni Credle
Department of Energy - NETL
sydni.credle@netl.doe.gov

PROGRAM CO-CHIAR, GENERATION
Xinsheng Lou
GE Power
xinsheng.lou@ge.com

TECHNICAL PAPER REVIEW COORDINATOR
Terri Graham
Hurst Technologies
terrig@hursttech.com

EXHIBIT COORDINATOR
Carol Schafer
ISA
cshafer@isa.org

HONOR & AWARDS CHAIR
Don Labbe
Schneider Electric
donald.labbe@schneider-electric.com

2016 POWID SYMPOSIUM COMMITTEE CONT.

PROGRAM CO-CHAIR, RENEWABLE AND DISTRIBUTED GENERATION
Rick Meeker
Process Control Solutions, Inc.
rmeeker@procontrolinc.com

PROGRAM CO-CHAIR, CYBERSECURITY
Michael Firstenberg
Waterfall® Security Solutions Ltd.
michaelf@waterfall-security.com

ISA PROFESSIONAL STAFF
Rodney Jones
ISA
P.O. Box 12277
Research Triangle Park, NC 27709
(919) 991-9418
rjones@isa.org

Newsletter Editor Update

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

I was reminded recently that I have been your ISA POWID Newsletter Editor for eight years now; my how time flies. The interesting thing is that ISA POWID has a 10 year term limit on that position so the search will begin soon to identify a new Editor. If you have an interest in volunteering yourself for that role you can contact our POWID Director, Aaron Hussey at ahussey@expmicrosys.com. To be eligible you must be an ISA POWID member in good standing as well as having the appropriate experience and skills and you must be appointed by the ISA POWID Director.

The Editor's job is to sustain member's interest in the division activities using the periodic newsletter. The POWID newsletter plays a very important role in the success of the division. The newsletter is one of the most visible services that the members look forward to receiving (at least we hope so). The newsletter is an excellent vehicle for disseminating technical information along with details concerning POWID and ISA activities.

So maybe you don't feel you have the skills or time to be the Editor; well you can always participate in the newsletter by being a content contributor. 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 would also welcome items of general technical interest. Please share with your colleagues any tidbits that have been beneficial to you in your job or in expanding your knowledge base. 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. If the article was not authored by you, please provide us with a statement that you have cleared publication of the material with the author. 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.

We want 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. I would like to encourage all of you to consider submitting something for future editions.

I hope 2016 is a good one for each of you. Have a great year!

Upcoming POWID and ISA Events

59th Annual ISA POWID/EPRI Symposium
27-30 June 2016
Electric Power Research Institute (EPRI) Conference Center
1300 West W.T. Harris Blvd.
Charlotte, North Carolina 28262 USA
See more at: https://www.isa.org/powid2016/

ISA Birmingham Section/Auburn University **46th Annual Fundamentals of Industrial Automation, Instrumentation, and Control Short Course**
3-5 May 2016
Revere Control Systems, 2240 Rocky Ridge Road, Birmingham AL, USA - See more at https://register.uce.auburn.edu/CourseStatus.awp?&course=C160503isa

You can find information on other ISA Events at www.isa.org/events

ISA POWID Symposium2015

58th Annual ISA Power Industry Division Symposium thanks its Champions

2015 Platinum Champion

beamex

2015 Gold Champions

EMERSON Process Management

POWER BUSINESS AND TECHNOLOGY FOR THE GLOBAL GENERATION INDUSTRY

2015 Silver Champions

Consumers Energy Count on Us Laboratory Services A CENTURY OF EXCELLENCE

EXCEL SERVICES CORPORATION NUCLEAR ENGINEERING CONSULTING

Honeywell

Schneider Electric

Setting the Standard for Automation™

2016 POWID/EPRI Symposium Invitation

by Susan Maley of EPRI
POWID Conference General Chair

The 59th Annual ISA Power Industry Division Symposium is coming to Charlotte, North Carolina on June 27-30, 2016 at the Electric Power Research Institute (EPRI) Charlotte Campus. If you and/or your company/organization are involved in power plant instrumentation, control and automation, then this is the conference for you. You will have the opportunity to hear directly from some of the industry's leading people about the latest technology and practices in the rapidly evolving power industry. The three day Symposium features important keynote speakers, technical presentation sessions, vendor exhibits, and adequate opportunities to interact with other participants. Along with and immediately after the event there will be other industry related meetings and training. As with past Symposiums, we are looking forward to student participation which is a wonderful way to welcome and encourage our next generation of I&C professionals. Our dedicated and valuable retirees are also encouraged to attend and in honor of those dedicated professionals and the students entering the workforce, we will be offering a special rate for both the retirees and the students.

The Symposium covers all types of power stations – coal, nuclear, gas-fired gas turbine/combined cycle, and renewable energy (hydroelectric, solar, wind, and biomass, etc.) - from all over the world. The conference is large enough to provide a comprehensive program of presentations and panel discussions necessary for professional development yet small enough to induce intimate conversations around special topics critical to your company's competitive growth and vitality. Exhibitor's participation is arranged so that you can learn about new products and support direct conversations about I&C related problems and solutions.

This year, the symposium's theme is "Instrumentation & Control for an Evolving Power Generation Landscape". The Program Committee, headed by Seth Olson, is putting together a program of technical papers (peer-reviewed) and presentations (subject to review) on a variety of topics. ISA Standard Meetings will be held for ISA67 (Nuclear Power Plants) and ISA77 (Fossil Power Plants) during the POWID Symposium. ISA training courses are being planned and will be offered to industrial professionals on boiler and power plant controls. Professional Development Units (PDUs) are provided for all session attendees to help meet PE license and CAP certification renewal requirements.

For more information, please visit https://www.isa.org/powid2016/ . The site includes a link to submit a paper abstract electronically along with conference and hotel registration links. The conference schedule and advanced program will also be posted at this location when they are available.

For information on becoming a Symposium Champion at the Platinum, Gold or Silver level or to purchase exhibit space, please visit the same website or contact Carol Schafer of ISA at cshafer@isa.org or (919) 990-9206. An Exhibitor Prospectus as well as an Exhibitor Contract is also available on the website for your review.

We look forward to seeing you at this year's POWID/EPRI Symposium!

POWID Awards Nomination Request to all POWID Members

You can tell from the quality of the presentations at our POWID Symposium and the discussions between attendees that a lot of talent resides in ISA's Power Industry Division (POWID). There are many individuals that display their talents in "beyond the norm" fashion. During your busy days, when such an individual is identified, recognize them by nominating that person, or an exemplary Power Facility for a POWID award as listed below:

- POWID Achievement Award
- POWID Service Award
- POWID Facilities Award
- Robert N. Hubby Scholarship

Nomination forms for these POWID awards are available through the POWID website at www.isa.org/division/powid/honors-and-awards/. Nominations for POWID Awards and Applications for the Hubby Scholarship are due by February 29, 2016.

Do not forget there are also ISA -- Celebrating Excellence and other awards that many POWID members are well deserving of. Information on those awards and how to submit nominations for them can be found at www.isa.org/members-corner/isa-honors-and-awards/.

If you don't see a POWID member's name that you respect or your facility's name listed below then it's time for you to nominate those members or your facility for an ISA Power Industry Division award.

Past POWID Achievement Award Recipients are:

2015	Aaron Hussey	Expert Microsystems
2014	Joseph Bentsman	University of Illinois
2013	Robert Peltier	Power Magazine
2012	Daniel Lee	ABB, Inc.
2011	Jacques Smuts	OptiControls, Inc.
2010	Xinsheng Lou	Alstom
2009	Dale P. Evely	Southern Company Generation
2008	Allan "Zeke" Zadiraka	Babcock & Wilcox Company
2007	Dr. Robert Smoak	Tennessee Tech
2006	Donald Labbe	Invensys
2005	Jeffery Williams	Emerson Process Management
2004	Donald Christopher	Reliant Energy
2003	Frank Ryan	Leeds & Northrup Company
2002	James Batug	Pennsylvania Power & Light
2001	Leonard Gruber	Westinghouse Electric Corporation
2000	Ronald W. Hicks	Black & Veatch
1999	Ronald H. Johnson	Sargent & Lundy Engineers
1998	Cyrus W. Taft	Consultant
1997	Robert W. Hill	Amtech Services
1996	Robert N. Hubby	Max Controls Systems
1995	Edwin M. Good	Florida Power Corporation
1994	Marjorie Widmeyer	Washington Public Power Supply
1993	Harold S. Hopkins	Utility Products of Arizona
1992	Joseph M. Weiss	Electric Power Research Institute
1991	Richard Hottenstine	Gilbert/Commonwealth
1990	Paul Kenney	Forney
1989	Gordon R. McFarland	Combustion Engineering
1988	Peter J. Clelland	Philadelphia Electric Company
1987	Q. B. Chou	Ontario Hydro
1986	Robert N. Buschell	Ebasco Services Incorporated
1985	John E. Coles	New Orleans Public Services Company

1984	Robert L. Criswell	Foster Wheeler Energy Corporation
1983	Porter J. Womeldorf	Illinois Power Company
1982	Theodore C. Reitz	Gibert Associates, Incorporated
1981	Richard H. Morse	Leeds & Northrup Company
1980	Richard T. Jones	Philadelphia Electric Company
1979	Samuel G. Dukelow	Bailey Controls Company
1978	Oliver W. Durrant	Babcock & Wilcox Company
1977	Alfred Watson	Westinghouse Electric Corporation

Past POWID Service Award Recipients are:

2015	Don Labbe	Schneider Electric - Foxboro
2013	Cyrus Taft	Taft Engineering
2012	Joseph Weiss	Applied Control Solutions
2011	Robert N. Hubby	ISA and ASME Life Member
2009	Stephen "Skip" Wells	Southern Company Generation
2008	Jim Redmond	Southern California Edison (retired)
2007	Dan Antonellis	Invensys
2007	Roger Hull	Emerson Power & Water Solutions
2006	Denny Younie	Wood Group
2005	Wayne Holland	Southern Company Generation
2004	Dale P. Evely	Southern Company Generation
2003	Daniel Lee	ABB Bailey Controls
2002	Gary Cohee	Applied Control Systems
2001	Rudy Neustadter	Raytheon Nuclear Group (retired)
2001	Harold Sternberg	ABB Bailey Controls
2000	Dan Antonellis	Invensys-Foxboro
1999	Wayne Holland	Southern Company Generation
1999	Rudy Neustadter	Raytheon Nuclear Group
1996	Don Christopher	Houston Lighting & Power
1994	Bob Hill	Amtek Services, Inc.
1994	Roger Hull	Emerson

Past POWID Facility Award Recipients are:

2015	John E. Amos Power Plant	American Electric Power
2014	MWt Chemical Looping Test Facility	Alstom Power
2012	Weston Unit 4	Wisconsin Public Service
2011	Boiler Simulation Test Facility	Alstom
2009	Rutenberg Power Station	Israel Electric
2008	Morgantown Generating Station	Mirant, Mid-Atlantic LLC
2007	Sim Gideon Power Plant	Lower Colorado River Authority
2006	Independence Steam Electric Station	Entergy Incorporated
2005	C. P. Crane	Constellation Energy
2004	Monticello Steam Electric Station	TXU Energy
2003	Elrama Power Plant	Reliant Energy
2002	W. A. Parrish Power Plant	Reliant Energy
2001	J. H. Campbell Plant	Consumers Energy
2000	Sundance Power Plant	Trans Alta Corporation
1999	Heskett Station	Montana-Dakota Utilities
1997	Mount Storm Power Station	Virginia Electric Power
1996	Gibson Power Station	Cinergy
1995	T. B. Simon Power Plant	Michigan State University
1994	Oklaunion Power Station	Central & Southwest
1993	Gaston Power Station	Alabama Power
1992	Eddystone Power Station	Philadelphia Electric Company

Past Robert N. Hubby Scholarship Recipients are:

2014	Breanna Bancheri	Rutgers University
2012	Simone Van Fermin	Rutgers University
2010	Michael Adams	Ohio State University
2008	Sharanya Jaganathan	
2006	Brandon Cavello	Pennsylvania State University

Have Pilots Forgotten How To Fly?

By: Allan J. (Zeke) Zadiraka
ISA POWID Excom Member Emeritus

The Federal Aviation Administration released a report, "Enhanced FAA Oversight could Reduce Hazards Associated with Increased Use of Flight Deck Automation", AV-2016-013, on January 7, 2016 which received a lot of attention in the media. While most of the media attention focused on the report's contention that pilots manual flying skills have greatly decreased due to dependence on autopilots to fly the planes to improve efficiency and reduce pilot workload, the report also emphasized the pilots reduced ability to monitor and determine that the flight deck automation is operating correctly and to quickly ascertain the state of the aircraft and determine the needed action when the autopilot suddenly rejects to manual control.

Based on my observations of recent incidents in power plants, a similar question would be "Have Control Room Operators Forgotten How to Operate?" The reliability of the controls and instrumentation in the power plant has greatly increased since I started in this industry in the 1960's. Operators are seldom called upon to take manual control of major control loops and often implement the wrong control actions when they do. It has become more common after an incident to hear testimony from the operator such as "didn't need to monitor the boiler because the boiler controls were on auto".

I doubt there ever will be a control system installed that does not have one or more "Gotcha's" waiting for the right set of circumstances to develop. The operator is expected to immediately recognize the problem and take the correct actions to mitigate the problem. In too many cases, this does not occur.

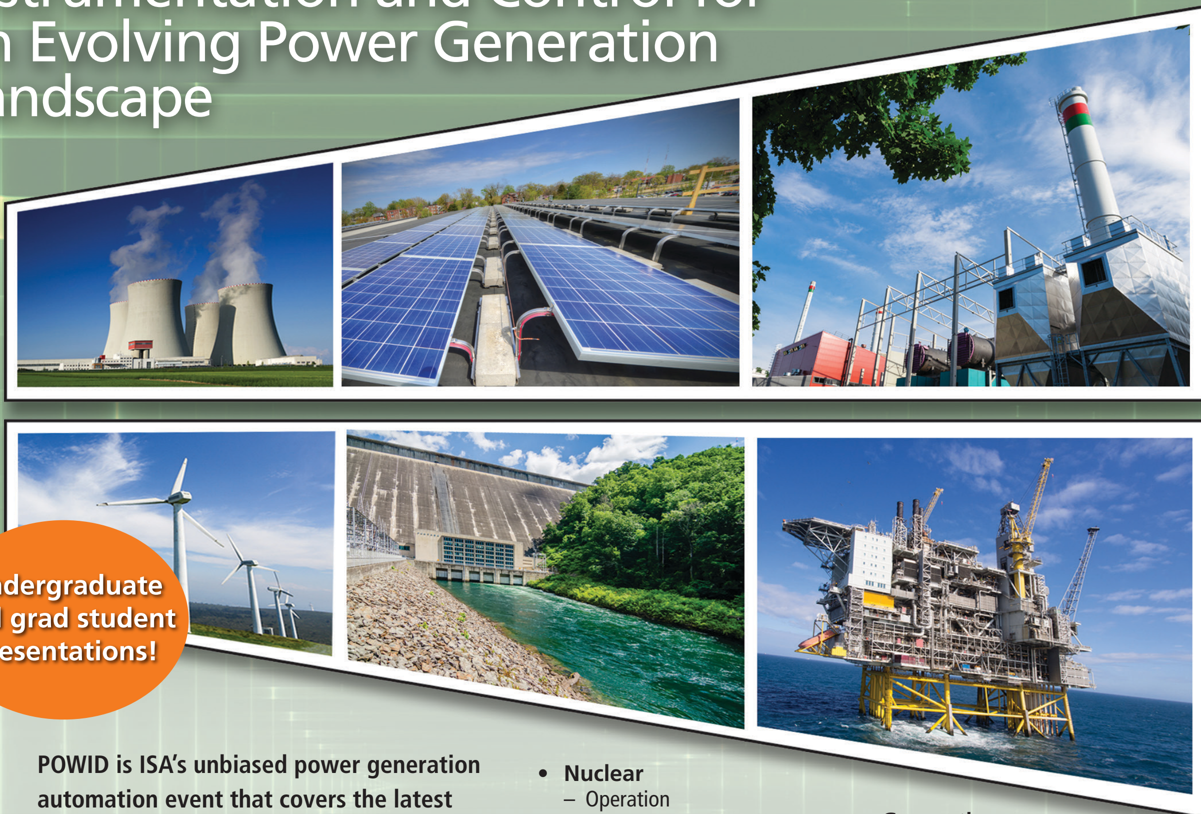
For the most part, operating a power plant is boring; the unit just sits there generating megawatts and drawing straight lines on the trend displays. The operator is left to perform minor tasks which do not contribute to improving his capabilities to monitor, understand and operate the major systems. The design of the Human Machine Interface (HMI) and alarm systems do little to support the operator in monitoring that the control system is functioning correctly or identifying what corrective actions to perform when his manual intervention in the operation of the plant is required. What displays that are provided to allow the operator to identify problems are often not up on a monitor in the control room. Since all they normally show is that all is well, the perception is that there is no need to monitor them continuously or even on a regular basis.

While operators need to be trained on procedures and response to typical events such as loss of feed pumps, they also need training to improve their situational awareness and response for slowly developing events such as process or instrumentation failures or degradation. While the control system designer needs to reduce the number of "Gotcha's" that exist in systems, attention must also be paid to design of displays and control station architecture to support the operator. Operators learn to operate the control system they have, no matter how poorly designed. When unforeseen conditions develop, the operator is responsible for implementing corrective actions to mitigate the incident. Can your control room operators actually operate the plant on manual?

Setting the Standard for Automation™

Power Generation:

Instrumentation and Control for an Evolving Power Generation Landscape



Undergraduate and grad student presentations!

POWID is ISA's unbiased power generation automation event that covers the latest technical innovations in power, nuclear power, and power instrumentation and controls.

Paper and presentation topics include, but are not limited to:

- **Nuclear**
  - Operation
  - New Nuclear Plants
  - Programmatic Issues
- **Fossil**
  - Environmental Control Systems
  - Combustion Turbine and Combined Cycle Plants
- **Hydroelectric/Renewables**
  - Innovations
  - Challenges
- **Generation**
  - Cybersecurity
  - Equipment Development
  - New Generating Plants (non-nuclear)
  - Advanced Control Technology and Applications
  - Human Factors Engineering
  - Fleet Management

Earn valuable PDHs and CEUs* just for attending!

*Separate registration and fee required

See program updates at:
www.isa.org/POWID2016

ISA thanks our 2015 Champions

Platinum
Beamex

Gold
Emerson Process Management
***Power* magazine**

Silver
Consumers Energy
Honeywell
Excel Services Corporation
Schneider Electric

2016 Champions

ABB
POWER

Sponsorship opportunities still available.

Contact Carol Schafer at
cschafer@isa.org

ISA POWID Symposium2016

27–30 June 2016
Electric Power Research Institute (EPRI)
1300 West W.T. Harris Blvd.
Charlotte, North Carolina 28262 USA

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

ISA POWID Goals for 2016

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 is adopting the framework (see figure below) that was established by the vision. This article highlights 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.

CONTENT

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.

Objective	Actions
Develop standards in fossil (77) and nuclear (67) power	• Identify collaborative opportunities in 67 & 77 standards between ISA, EPRI, and other organizations • Continue 77 standards in progress by continuing subcommittee meetings • Continue conducting face-to-face meetings at annual symposium
Provide strong technical programming at annual controls & instrumentation symposium	• Add cycling/operational flexibility focus in technical tracks • Add Industrial Internet of Things (IIoT)/Big Data focus in technical tracks • Continue session on Monitoring & Diagnostics (M&D) • Continue student session and networking reception • Continue session on Cyber Security
Address industry needs in training	• Review training courses and identify new areas of focus • Offer at least one highly relevant course during annual symposium
Present relevant content to the membership	• Assemble and publish a newsletter three times a year with content relevant to our membership • Update and maintain the POWID website to provide an always available portal to information about POWID and its activities • Archive all POWID technical papers (1959 – Present) in ISA Technical Paper database

DATA

POWID will use data to understand trends, make decisions, and develop products and services that align with market needs.

Objective	Actions
Use feedback to direct changes and continual improvement activities	• Use EPRI and ISA data & feedback to direct annual symposium Marketing by analyzing the Voice of the Customer (VOC)
Collect feedback of membership and symposium attendees	• Use feedback forms during and after annual symposium to collect areas for improvement and areas to continue what works well • Collect feedback from suspended members by email survey • Collect feedback from members through member survey

Objective	Actions
Track progress on goals aligned to 5 strategic directions	• Keep a document with living updates (review once/quarter and provide feedback to Executive Committee) • Identify and implement method(s) to streamline the process

COOLEST DELIVERY

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

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

CYBERSECURITY

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

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

ADVOCACY

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

Objective	Actions
Engage college students and young professionals	• Identify a candidate for the Robert N. Hubby scholarship prior to annual symposium • Reward a candidate for the achievement award recipient scholarship • Continue student track at annual symposium • Identify marketing focus for young professionals and engage in annual symposium
Participate in directing local Science, Technology, Engineering, and Mathematics (STEM) education curriculum and teacher training	• Attend and contribute to JM Robinson High School Manufacturing and Automation STEM program in Concord, North Carolina to make faculty/students aware of ISA and the various divisions • Use this activity as a learning experience for engagement of additional POWID members with their local community STEM programs

For more information on POWID's goals for 2016, contact Aaron Hussey at ahussey@expmicrosys.com.

DR. GOODDATA (#9)

By Ronald H. Dieck
Ron Dieck Associates, Inc.
RonDieck@aol.com

Welcome again to Dr. Gooddata's arena. As we did last time, today we'll discuss combining systematic and random uncertainties. We will pay particular attention to the correlated errors and their uncertainties. Here, sometimes correlation will help us (lower the uncertainty) and sometimes hurt us (ouch!), increase the uncertainty. How does this work?

Let's begin by reviewing (sorry, no offense intended) the basics of the combination of uncertainties for the example of two weights weighed separately and their results summed to get the total weight.

First, we wrote the equation for the result. It was:

$$W_T = W_1 + W_2 \tag{1}$$

Where W_T = The total of the two weights
W_1 = The first test weight
W_2 = The second test weight

In this situation, we have the uncertainties for each of the test weights. That is, $b_{W_1}, b_{W_2}, s_{\overline{W}_1}\, and\, s_{\overline{W}_2}$ represent the systematic standard and random standard uncertainties of weights one and two respectively. (Note that these standard uncertainties are all equivalent standard deviations of the average.)

The combination of independent systematic standard uncertainties to obtain b_R, the systematic uncertainty of a result, was done as follows:

$$b_R = \left[\sum\left(\frac{(\partial X_R)}{(\partial X_i)}\right)^2 (b_i)^2\right]^{\frac{1}{2}} \tag{2}$$

The equation for combining independent random standard uncertainties is:

$$S_{\overline{X}_R} = \left[\sum\left(\frac{(\partial X_R)}{(\partial X_i)}\right)^2 \left(S_{\overline{X}_i}\right)^2\right]^{\frac{1}{2}} \tag{3}$$

Both of these equations assume the errors are independent.

Certainly (intuitively obvious to the most casual observer) the random errors are independent. That is, they are unrelated.

However, in our weighing example, the systematic errors are correlated. That is, a systematic error in weight one is the same error in weight two. That presents us with a problem. How do we use Equation 2 when the errors are not independent?

Well? How? Think? It is trick question. We don't use Equation 2; we use an expanded version ~~of the~~ Taylor's Series equation that includes the correlation term. That more general equation looks like the following.

$$b_R = \left\{\sum_{T=A}^{B}\sum_{i=1}^{N_T}\left[\left(\theta_i b_{i,\mathrm{T}}\right)^2 + \sum_{j=1}^{N_T}\theta_i\theta_j b_{(i,\mathrm{T}),(j,\mathrm{T})}\left(1-\delta_{i,j}\right)\right]\right\}^{1/2}$$

What a mess! However, for our example, the detail above reduces to Equation 4 following.

$$b_{W_T} = \left[\left(\frac{\partial W_T}{\partial W_1}\right)^2 b_{W_1} + \left(\frac{\partial W_T}{\partial W_2}\right)^2 b_{W_2} + 2\left(\frac{\partial W_T}{\partial W_1}\right)\left(\frac{\partial W_T}{\partial W_2}\right) b_{W_1} b_{W_2}\right]^{\frac{1}{2}} \tag{4}$$

We will show below that, for our case, Equation (4) reduces to Equation (5). That is:

$$b_{W_T} = 2b_{W_1} \tag{5}$$

Note that the systematic uncertainty of the total of the two weights is twice the systematic uncertainty of one weight. When they were independent, that factor was the square root of two, not two.

This is intuitive. Consider this. If the first weight has a systematic error of one ounce as does the second. When you add them together, the systematic error for the sum will be two ounces! Eureka! We have found it!

How do we go from Equation 4 to Equation 5 analytically?

First, we wrote the equation for the result, the total of the two test weights. It was:

$$W_T = W_1 + W_2 \tag{1}$$

Where W_T = The total of the two weights
W_1 = The first test weight
W_2 = The second test weight

In this situation, we have the uncertainties for each of the test weights. That is, $b_{W_1}, b_{W_2}, s_{\overline{W}_1}\, and\, s_{\overline{W}_2}$ represent the systematic and random standard uncertainties of weights one and two respectively.

We now note that the partial derivatives in Equation (4) are all unity. That is:

$$\left(\frac{\partial W_T}{\partial W_1}\right) = 1 = \left(\frac{\partial W_T}{\partial W_2}\right) \tag{6}$$

We also note that the systematic standard uncertainties of both weights are identical. That is:

$$b_{W_1} = b_{W_2} \tag{7}$$

Now, substituting Equation (6) and Equation (7) into Equation (4), we obtain:

$$b_{W_T} = \left[(1)^2 (b_{W_1})^2 + (1)^2 (b_{W_1})^2 + 2(1)(1) b_{W_1} b_{W_1}\right]^{\frac{1}{2}} \tag{8}$$

Equation (8) becomes:

$$b_{W_T} = \left[4 b_{W_1}{}^2\right]^{\frac{1}{2}} = 2 b_{W_1} \tag{9}$$

q.e.d. (I love saying that.)

So, we have the analytical solution that shows that the intuitive solution is correct. That is, the systematic standard uncertainty of the total of two weights weighed separately and then added is twice the systematic uncertainty of a single weight when the errors (and uncertainties) are correlated.

How can we put this higher learning into some practice? Next time, we'll launch into some practical considerations by taking a close look at a measurement uncertainty computation for a calculated result requiring detailed uncertainty propagation. Some of the errors (and uncertainties) will be correlated and some won't. We'll apply the principles shown in the past three or four Dr. Gooddata articles. It should be fun. I can't wait!

Until then, remember, use numbers, not adjectives!

Status of Control and Instrumentation Systems Deployment in Indian Power Industry

By: Alok Shrivastava – ISA POWID Excom Member
Additional General Manager, Project Engineering (Control & Instrumentation), Engineering Office Complex NTPC-Noida, India
alokshrivastava@ntpc.co.in

KEYWORDS:
Indian Power Sector, Renewable Energy, NTPC, Control and Instrumentation (C&I), Renovation and Modernization, Environment Protection, Availability, Reliability, Affordability, Safety, Regulatory Compliance, Land/Water Conservation, Distributed Control System (DCS),Cyber Security, Interoperability, Scalability, Obsolescence, Standardization

Indian Power Sector
The Indian Power Sector has evolved a lot in the last many years. It is rapidly under going tremendous technological and policy changes, spearheaded by the Government of India.
The Power Sector is under intense focus by policy makers, regulators, utilities in generation, transmission and distribution, end consumers and last but not the least, the environmentalist.
Even with the back drop of economy turmoil across the world and recession in emerging markets, the country's economic growth is predicted at around 7.5% based on various government and non-government estimates for this financial year (Apr-2015---March-2016). Power will be the engine driving the growth of the Indian economy.

Comprehensive plans to protect environment with sustainable development have been included as an integral component of power sector development of the country today. Government of India's two-pronged approach is to cater to the energy demand of its citizens while ensuring minimum carbon emissions. India is running one of the largest renewable capacity expansion programs in the world, with an aim to achieve 175 GW of renewable energy capacity by 2022. Out of this 175GW renewable energy, solar power alone will contribute around 100 GW, an eye popping figure, in terms of the impact, it is going to create on energy spectrum of the country. Expectedly, this has created huge excitement not only among the Indian investors and industries but also among the international investors and industries.

With the recent conclusion of Paris Climate Conference (COP-21) talks recently, India's Intended Nationally Determined Contribution (INDC) program for climate change initiatives is going to remain one of the core objectives to be achieved by all stake holders of Power business in India.

Coal, being the cheapest and abundantly available energy-source in India, will remain the main stay fuel for power generation. Technologies such as Ultra Supercritical (USC), right blending and greening of coal, are therefore garnering greater importance, to meet India's need for clean and affordable power to all.

As discussed before, renewables, especially solar, is now the cynosure of all stake holders in power generation to provide the quick fix solution to "dirty fossil fuels", just to even out the "ill effects" of fossil fuel based power generation on environment.

Despite the falling prices in solar photovoltaics (PV) due to technological advancement and economy of scale (In India it is expected that grid price parity of solar PV generation is expected to be achieved by 2016-17), it has thrown a set some of the new challenges such as:

- Grid integration requiring sophisticated grid operation and control centers
- Intermittency of operation due to day/night/seasonal variations creating cyclic loading resulting in high stress(failures) and high fuel consumption on base load stations
- Still large foot-prints requirement for solar PV plants- land availability is now one of the greatest challenge in India

Key challenges before Indian Power Utilities
Amidst the business environment described above, the Indian power sector is obligated to provide power to consumers, while keeping the following aspects as integral components of their power generation business -

- <u>Environment Protection and Conservation</u>
  The Power generation utilities to increasingly adopt carbon neutral and carbon free generation portfolios, aims at efficient use of coal, deploy superior technologies for emission control and abatement, try to extract energy from waste towards this significant objective.

- <u>Availability and Reliability (Quality power) of power</u>
  The availability of reliable power is the need of the hour. Due to increasing integration of renewable energy sources in the Indian grid system, real time operation management

of generation and distribution will be a crucial link for achieving this objective of providing power in abundance with requisite quality.

There are issues like wide fluctuations in the grid frequency in the country due to large demand supply gaps. There are evolving regulatory requirements of primary and secondary frequency controls. Large scale renewable energy sources integration to Indian Grid will lead to cyclic operations of many high capacity plants, those were conventionally conceived to be base load plants.

This requires relook and redesign of control system loops to ensure plant stability (more so for the supercritical units) during rapid ramping up/down. This again calls for better and flexible control algorithm and necessary skills to do the same. The smart way to manage grid will require all deployment of technological solutions such as smart metering, effective communication networks, demand forecasting tools for effective power flow management, and as explained earlier, smart controls at generation end!

Quite an exciting set of opportunities for the engineers and technologist!

- <u>Affordability of power and conservation of water and land.</u>
  Land availability for industry use is getting scarier in this part of this world. Similar constraints are increasingly being faced for water availability for coal based plants. This has a direct bearing on cost of power generated from a new power plant. Indian coal is typically characterized by large ash contents (as high as 40 %). This requires large land-pool for ash disposal, though recent regulation stipulates 100% ash utilization by coal based power plants. New engineering and technological solution such as compact plant layouts, air cooled condensers, increasing cycle of concentration of cooling water system, Zero liquid discharge from plants, better ash utilization techniques are being implemented to overcome the land and water constraints.

- <u>Safety and security of critical Power Plants assets.</u>
  For the safety of plant and people the Indian plants have been equipped with state of the art control and protection system complying with international standards. How-ever now a days, majority of the countries around the world are facing a daunting task of protecting their critical industrial assets for a probable international terror attack, both from physical and cyber world. This redefines the safety needs in terms of ensuring perimeter security and cyber security of our plants automation and information networks.

NTPC in Indian Power Sector

NTPC, a government of India's owned, stock exchange listed organization, has completed 40 years of excellent operations as the largest power utility of country. It is rated amongst the best and largest power utilities in the world as well. At present, NTPC owns a generating fleet of over 45,500 MW (out of India's installed power capacity of 280,000 MW) having a mix of fossil based, hydro and renewal (mostly Solar PV) power plants. NTPC aims to become a 75,000 MW plus company by 2017 and 128,000 MW Company by the year 2032 with increasing share of renewable/hydro in its generating fleet.

NTPC is equipped with in-house capabilities to conceptualize, engineer, erect, commission, operate and maintain (including renovate and modernize) plants all over the country and has equipments/systems from almost all major Original Equipment Manufacturers (OEM's) around the world. Since its inception, NTPC is known to spear-head all major technology initiatives in the country.

The control and instrumentation systems in NTPC power plants form a major backbone of power plant operation, monitoring and controls ensuring safe, reliable and efficient operations. Since its inception in 1975, NTPC plants have been equipped with state of the art control and monitoring systems. To meet dynamic business and regulatory requirements of the company, control and instrumentation systems deployed at NTPC have directly or indirectly contributed in a big manner in meeting or even surpassing the organizational needs and requirements.

The following sections describe the status of control and instrumentation systems deployment and the issues being faced thereof in Indian power sector in general, and NTPC in particular, and how control and instrumentation systems can overcome the current issues and challenges being faced by Indian power utilities.

Control and Instrumentation (C&I) deployment at NTPC:

As discussed previously, the Control & Instrumentation systems form the integral component for all the strategies to achieve many business challenges. Let us understand how control and instrumentation can contribute, directly or otherwise in achieving the same. Though many, contribution of C&I systems may be in general and may find universal applicability, some aspects are very unique to Indian power sector requirements

- <u>Environment protection and conservation through effective on line monitoring instrumentation</u>
  Since its inception, NTPC plants have always been designed with systems and instruments for state of the art monitoring of emissions, even though the environmental norms were not as stringent as they are today. As discussed previously, now-days there is a great concern for environment emission, especially for the fossil based power plant, in the country. Many equipments such as high efficiency Electrostatic Precipitator (ESP's) and Flue Gas desulphurization (FGD)'s equipments are being put in place for mitigating many environmental emissions from plant. Further these equipments are well supplemented by measurement and monitoring techniques for judging the performance of these equipments in reducing the emissions of the flue gases, Suspended Particulate Matters and effluents from water discharge from the plant are being monitored, that will greatly help in better monitoring, there by mitigating environmental emissions.

Following parameters are generally monitored in a coal fired power plant on real time basis.

- <u>Emissions due to combustions</u>
  Continuous Emission Monitoring (CEMS) including measurement of SO2, NOX, CO, CO2, Particulate emission monitoring systems (Stack Opacity Analyzer), Mercury & Oxygen (High and low temp.) analysis.

- <u>Ambient Air Quality Monitoring System (AAQMS) for monitoring the air quality in plant vicinity</u>
  Under AAQMS, following monitoring solution is adopted. Total Suspended Particulates (TSP), Particulate matter PM10, PM2.5, NOx, SO2, CO, Mercury and Ozone

Monitoring of meteorological parameters such as wind speed/direction, Air Temperature, RH, solar radiation, rain

Data Logger/Data acquisition system for AAQMS and Meteorological Stations with availability of the data at plant level and corporate Head Quarter (HQ) level (NTPC HQ Noida/ New Delhi)

- Effluent (Effluent Quality Monitoring System)
  Though concept of zero liquid discharge from plant is fast catching up, how-ever for existing power stations parameters such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total suspended Solid (TSS), Oil in Water (OIW), pH, Conductivity, flow and temperature measurement of the effluent water from plants are locally and centrally monitored for all the plants as a part of effluent water monitoring systems.

- **Availability and reliability of power (Quality power) through deployment of well-designed state of the art Control and instrumentation systems**
  The practices of International Competitive Bidding (ICB) is generally followed in awarding contracts by government companies like NTPC. This results in many international Steam Generator (SG) and Turbine Generator (TG) suppliers implementing the Indian power projects. For Control and Instrumentation system implementation, it creates many challenges in interface engineering in general and more specifically in realizing unit controls. This challenge has been overcome by us by designing customized unit control for a unique SG-TG combination. This will ensure better plant availability and reliability in operations.

  The control systems are generally provided by OEM's based on their standard offerings. Development and improvement in the control strategies, operation and protection of equipments and systems based on existing knowledgebase at NTPC, while at the same time adopting the latest practices around the world greatly ensure availability of reliable Power through NTPC plants. The engineering, operation and maintenance staff have to learn very quickly to operate and maintain these systems as there is little similarities in the Control systems offered by all leading DCS supplier that are still proprietary around the world.

  The focus during design and engineering stage of control systems is towards the improved reliability and availability of control and instrumentation systems there by facilitating availability and reliability of existing power capacities. The following areas are given due importance during the engineering of control and instrumentation systems:

  - Sensors selection and their redundancies
  - Final control element selection in terms of availability of diagnostics feature and response time
  - Instrumentation cabling concepts
  - Power supply system availability
  - Control system redundancies, control and instrumentation system powering and grounding schemes
  - Interlock/ protection and logic implementation as per OEM's recommendation and as per standard operating practices of NTPC
  - Adopting industry standards such as OPC /Modbus for seamless real time data communication between heterogeneous automation systems
  - Provisioning of improved diagnostics, alarm segregation, well-engineered HMI schemes, easy operator interface through Human Machine Interfaces Plant Information System (HMIPIS) implementation etc.
  - Ergonomically designed control rooms for 24x7 operations

  Reliability and stability aspects of power plant processes and systems can be further improved if some of the following aspects are taken care by the suppliers of these systems:

  - Quality of field instrumentation design well suited for Indian environmental condition of dust, humidity and temperature variation.
  - Field devices like instruments and actuators are provided with better diagnostics features. Field Bus technologies have been quite successfully adopted in petroleum sectors (refineries), but large scale penetration of filed buses in power sector is yet to be seen in Indian Power sector.

- **Power affordability and conservation of water and land**
  The Return on Investment (ROI) in any plant would improve if the assets of the plants are managed in an excellent manner.

  The control and automation systems become an important link between the modern asset management systems and the assets themselves. One of our very experienced and renowned head of operations used to tell us- "move the data not the people!"

  Through an integrated asset management solution with seamless integration of real-time plant information and other off line data, Asset Management of entire fleet of operations become very interesting and rewarding.

  With this concept, centralized real time operation monitoring of all nationwide generating assets (units) of NTPC has been achieved, way back in 2009, through enterprise wide integration of all DCS system with ERP systems. And now with the availability of geographically distributed plant data at one place, by deploying expert software for critical assets of the plants, advance proactive action, is remotely taken for all critical assets of NTPC.

  We have also adopted single family of DCS hardware for main plant as well as off-site (balance of plant) areas at NTPC. However for Steam Generator (SG) Burner Management System and Turbine Generator (TG) governing and protection system, still OEM supplied systems are used for green field projects. This has ensured reduced inventory, lesser expert main power requirement with focused maintenance strategies for C&I systems.

  These strategies have contributed in a big way towards reducing over-all cost of ownership of the plants and systems.

  - Conservation of Water and Land
    Few years back at NTPC, we used to have around 33 control rooms (large and small) for main power block

and off-site (balance of plant areas)! These control rooms require large foot prints thereby increasing the land requirement. With the advent of better networks such as high speed Ethernets and use of fiber optic based communication links for data communications in DCS, concept of common control rooms for many plant areas, have been introduced in last 10 years or so. Thus, we have now only 4-5 control rooms that caters to both Main plant (Boiler, Turbine and Generator-BTG) operations as well as for auxiliary plants (off site areas). Quite a contribution in reducing the control room areas foot prints, thereby reducing over-all land requirement for the power plant!

Remote operations of large size hydro plants are also being tested by us. That will further reduce requirement of large control rooms.

With newer generation of engineers less willing to be posted at remote sites of power plants, the challenge lies in implementing centralized operational and maintenance (O&M) center with highly reliable and responsive automation network for remote operation, diagnostics and maintenance services by experts. This will help in reducing overall land requirement for these plants, as infrastructure requirement for these O&M centers will be minimal in the vicinity of Power plants.

Every region in the world is witnessing fluctuating weather conditions. With erratic rains in Indian subcontinent, the water availability to plants is getting reduced day by day. Better water flow monitoring techniques at all suspected wastage zones and through integrated water balance monitoring systems, help in checking the water leakages and optimize water requirement. This concept has been implemented by us in NTPC. Further stringent Cycle of concentration (COC) norms for cooling water require real time monitoring of bio-film, pH, corrosion, deposits and residual chlorine. This is facilitated by implementing effective dosing control of chlorine and inhibitors of scaling and corrosion. All the above methodology is aimed for conservation of water in our plants.

- **Safety and security of critical Power Plants assets**
  - Safety of Plant equipments and People
    Safety had been and will remain the core of power plant life cycle. Control and instrumentation system form the core of realizing the process and equipment safety in the power plant. The control system functional testing during Factory acceptance Test (FAT) and commissioning checks also form a part of safety management system in our plant. With Safety Instrumented System (SIS) being widely used in other process industries such as refineries and fertilizer, the same systems can also be adopted for some of the power plant applications like Burner Management System (BMS), Chlorination, Hydrogen generation and Naphtha handling systems. How-ever the initiative should also be taken by the OEM's specifically by the suppliers of Steam Generator and Turbine.

    Many Turbine OEM's now provide SIL certified Turbine over speed protection/ other Turbine protection system for their turbines. Development of Safety functions for Burner Management systems (BMS) and turbine Safety systems in the green field/brown field power plant is a challenge. However initiatives have already been taken in NTPC to get SIL certified BMS systems and turbine protection system specifically under renovation and modernization jobs.

    Even during project execution the use of technology such as Close Circuit Tele-Vision (CCTV) based project monitoring is utilized in a big way to monitor safety compliance. As a safety conscious organization, NTPC has also taken initiative in this direction to establish a safety control room for monitoring project erection and commissioning activities.

  - External threats including Cyber threats for Automation systems
    With international terror spreading its arms like never before, the physical and cyber security of power plants assets is of extreme concern to all of us. At NTPC, we have ensured that automation systems, that are factory tested, are free from any cyber security holes. This is done by employing independent cyber security auditors. We have also adopted well defined cyber security policies and procedures and ensured regular audits by independent cyber security auditors during the O&M phase of plants. CCTV based system are deployed at present for keeping a close watch on all critical assets of the plants. These will be further strengthened with additional sensors and systems.

End user Concern and challenges of Control and Instrumentation systems

As an end user with sufficient experience of automation systems, some of the concerns and challenges that are to be addressed are as follows:

- Obsolescence
  Our fleet is aging and so obsolescence issue is confronting us. The fast changes in hardware (H/W) and software (S/W) technology are resulting in obsolescence of the DCS system. Despite the commercial off the shelf H/W (work stations/Servers) and operating systems generally provided for HMI of a DCS, there life-cycle is more ephemeral than the life of HMI application software developed by the DCS vendor. Thus there is mismatch in obsolescence cycle of HMI and control system of a DCS. Thus it requires differential obsolescence handling strategy for HMI and Control system hardware.

  Pace of technology development and technology validation
  The technology development and adoption happens in pockets and also at a disruptive pace. Many times the user is not aware and so he is not comfortable in accepting the technology. A methodology needs to be worked out so that user is taken in confidence about the technological development. The technology should be available from multiple vendors so as to provide competitive products through open competition enabling better choice for the end user of the technology. There is a need for independent bodies like ISA or ISA authorized entities, who can also validate new technology/solutions for the user specific usage. This will facilitate the technological development and faster deployment/acceptability of these technologies in power domain.

- Standardisation-Interoperability and scalability of the system
  If somebody wants to change the bulb or an electrical socket he/she doesn't bother about the size and form aspects. One can purchase it from the market assuming it will perfectly fit in the existing bulb socket. But for a DCS card can this be assumed? Though there has been substantial progress in terms of interoperability of devices like transmitters, in terms of other systems like DCS or PLC's lot is desired to be done.

  Can one buy DCS, off the shelve, the way one buy a mobile or a PC's and run a standard and validated control application software from another vendor? Is it possible to procure HMI software from outside and integrate it with any DCS/PLC system in the back end? All the stakeholders need to work as a team for fructifying the inter-operability of C&I systems/Sub systems.

  In the control system architecture, a solution needs to be thought by all automation system suppliers. An ideal solution would be an industry standard back plane and standard rack (say a 19" inch rack) of all the control systems with a USB kind of standard backplane interface so that modules of any automation supplier can be placed in. This helps in avoiding the dismantling of system even if the module needs to be changed because of the underlying electronics obsolescence.

  Similarly HMI applications should be OS/Hardware independent so that with commercial workstation /Server hardware/OS going obsolete, HMI software portability is both forward and backward compatible with the current HW/OS in vogue.

  Scalability aspects also needs to be taken care in C&I systems so that C&I systems can be scaled up based on futuristic expansions in power generation capacities. Standardization is another important aspects that is very important from end user perspective. Following are the areas that seeks immediate attention for standardization:

  - Standard programming language for DCS control systems. What is being sought after is a software functionality that is as easily available as mobile "Äpp", but is validated and certified for its use in critical controls. Further we need to have standardization of HMI system and integration of the same with underlying DCS system of any make. There is an urgent need to develop standard similar to IEC61850 developed for Numerical Relays and Networking systems. A real Service oriented architecture (SOA) for the DCS/PLC's is the need of the hour.
  - Standard network and security architecture and frame work for DCS systems.
  - Standard power supply specifications for DCS systems. Currently acceptable input to DCS vary from 240 V AC/110 VAC/24 V DC/48 V DC system. Further outputs to DCS module may vary from 12V/5V/15 V/24 V depending on application. There is need for standardization of input and output power supply levels for DCS/PLC's.
  - Standard Form/Fit and back planes for control system resulting in standard size of Control System cabinets.
  - Standard Form and fit for Field devices.
  - Standard earthing and grounding requirements for the control system.

- **Skill development and domain expertise**
  Every business domain requires a specific skill set. The beauty of control and instrumentation systems is that they tend to be generic in nature. A DCS can be used for refinery application at the same time it can be customized for a power application. However it requires a deeper understanding of domain and necessary skill set of the DCS system so that both can be matched effectively. This is an area of concern for all users in India. There is a need of the hour to develop domain specific automation professionals who understand the business much deeper. This would greatly meet the business specific demands. There is shortage of skilled man power as IT attracts major chunk of the automation people. There is an urgent need to attract the best talent so that the discipline can benefit from the brightest mind of the country.

  As the C&I system tend to be complex by nature, so training facilities in terms of quality and quantity needs to be developed so that more manpower is available for effectively manning these systems.

- **Interaction between automation suppliers and OEMs**
  A very critical aspects of power generation business is that the major OEMs of mechanical systems like Boiler and turbine have their own designed proprietary control systems for the protection and control of their equipments. These systems are also now being offered for general purpose automation applications. Thus one would tend to notice that functionality of some control systems are more oriented towards oil sector, while for some control systems these are more functionally oriented towards power domain. However domain specific function offering is needed so that control solution is gainfully adopted by the relevant domain of industries. A classic example is that of field bus technologies, that are very seamlessly adopted for Refineries and petrochemical application, but wide spread application in power domain is yet to be seen.

Conclusion

Control and Instrumentation will permeate hitherto un-touched arenas of power generation domain. The onus is on the suppliers, users, consultant and academician to address the problems typically faced by the control and instrumentation implementer in power domain. The C&I systems should offer all the merits that present day Information, Compunction Technologies (ICT) offer to the users, without any compromise on the stability and responsiveness of these systems. More often than not, it is observed that the OEM's of major equipment supplier such as Boiler and Turbine, are quite conservative, thereby limiting the acceptance of latest C&I systems by them. The forum's such as ISA POWID should take the lead and ensure that latest automation system delivery through such OEM's.

Acknowledgement

I would like to thankfully acknowledge useful insights provided by my colleagues Mr. Rajeev Khanna, Additional General Manager –Project Engineering – (Control and instrumentation) and Mrs. Arundhati Bhattacharya General Manager/Head of the department-Project Engineering – (Control and instrumentation) while discussing the various aspects during preparation of this article.

Disclaimer
The views expressed in the above paper are of the author(s) and should not be a reflection of NTPC management/Government of India views or policy-direction.

POWID Membership Recognition

July 2015 through December 2015

By: Dan Lee
POWID Membership Chair

The Power Industry Division (POWID) of ISA continues to grow. We would like to welcome all of our new POWID members and our new student POWID members. We hope you will take advantage of everything POWID has to offer for your work and your career including the opportunity to network with power industry professional colleagues across the globe. Our primary goal is to provide a means for information exchange among engineers, scientists, technicians, and managers involved in instrumentation, control and automation related to the production of power. POWID is active in developing industry safety and performance standards, working closely with two ISA standards committees—ISA67, Nuclear Power Plant Standards, and ISA77, Fossil Power Plant Standards. The Division also conducts technical training and sponsors awards for power plants and individuals advancing instrumentation and control within the power industry. POWID welcomes your involvement in our division activities. Opportunities are available to provide information for our newsletter and web site, to develop papers for presentation at our annual conference, and to participate in our division's management structure. It's a great way to get to know other industry professionals, to gain professional recognition, and to keep informed!

Welcome New POWID Members

- Majed Al Breiki
- Senthil Arumugam, Area Vice President, Pricol Technologies Inc.
- Dwight J Beard, Manager Automation Control Valves, Wolseley Industrial
- David Beasley
- Nate Carroll, World Wide Technology, Inc
- Dharminder Dargan, Assistant Vice President Cyber Security, Leidos
- Frans Victor De Beer, Senior System Control Engineer, CONCO Energy Solutions
- Mr Rafael Bissoli Dias, Technico Controle Processos
- Erdem Dirin, Key Account Manager, Ars Endustriyel Kontrol A.S.
- Steve Evans, Powerlink
- Ms Faye Farahmand
- Michael Freeman, President, Instrumentation, Controls & Electrical Contractors
- Chris Hamelin, Sales, Samson Controls
- Justin Hansen, Controls Engineer, Victory Energy Operations LLC.
- Jacob Hinsch, CEO, INS Scandinavia
- William Irvine
- Julio, Senior Designer, Hazen and Sawyer
- Eric Keller, EDG, Incorporated
- Sreedeep Krishnan, Assistant Professor
- Allison Mason-Boodoo
- Marco Mendez, Automation Engineer, Chevron Phillips Chemical Company LP
- Kapil Methi, Test Manager, ABB LTD.
- Sanjib Muhury, Manager commissioning (I&C), Dubai Electricity and Water Authority
- Ms Amaka Obi, Project Assistant, Acclerated Energy LTD
- Mr Olakunle Abiola Olabode, Systems Engineer, BT Technologies Limited
- Odesa Owrakijat, electrical engineer, Kennedy/Jenks Consultants
- Sonu Pal, Market Research, BCC Research
- Thomas Quek, Redcon Security Advisors
- Abhishek Ravindra
- Mr Faran Rolingson, Control Engineer Sr
- James Rutledge, Station Engineer, Jacksonville Electric Authority
- Mr James M Sanderson, Field Sales Engineer
- Daniel Sangines
- Manuel Santander
- Mr Jose Roberto Santiago Junior
- Aung Than Shwe
- Mr. Eric Spink, Manager Systems And Controls
- Mr. Ronald Stapleton, Water/WasteWater Specialist
- Tamas Tribolt, I&C Electrical Supervisor, Astoria Generating Co
- Mr Ogbu Samuel Ukpa, Skytrain Digital Consults
- Mr Anderson De Candido Vieira, Supervisor

Welcome New POWID Students

Ms Savitri Yankappa Alawandi
Ms Shree Raksha B S
Mr Andrew Ray Bailey
Mr Hemanth Bandi
Ms Aqhwarya Biju, SRM University
Mr Hrushikesh Boyini
Mr Glendon Jay Briggs
Mr Dushyant Singh Chauhan, SRM University
Mr Tirthankar Das, SRM University
Mr Renan Freitas De Oliveira
Mr Umang M Gohel
Damara Harsh
Mr Matt James Kohnen
Prajakta Vinod Koratkar
Mr Bhavik N Lad
Mr Benjamin Gregory Leas
Brendan James John McCartines
Mr Jason Allan McDonell
Mr Carimi Carpinetti Merij
Mr Jeffery Karl Morris
Ms Ragini B N Balakrishna Nanduri
Mr Jordan Rinehart Nussbaumer
Mr Dhruv Panchamia
Mr Rinkeshkumar R Patel
Mr Dhwanil K Patel
Mr Sidhant Pattnayak
Mr Italo Coelho Pereira Junior
Mr Paulo Henrique Perovani
Miss Divya M Potla
Mr Venkatesh Pragada, SRM University
Mr Pranav S Prajapati
Jordan Michael Proctor
Ms Suhasini R
Mr Sidharth Raj
Ms Apsuara Devi Rajendran
Mr Tuhin Ranjan
Kalyan Kumar
Ravi Kumar
Mr James B Reed
Mr Kalvin Arthur Reed

Mr Adithya Sampath
Mr Anderson Junio Neves Santos
Raphael Santos Passos
Mr Fransergio Moro Scopel
Ms Sarbani Sen
Miss Khushbu C Shah
Miss Rajvi K Shah
Ms Rachna Shaily
Rishi Kiran Shankar
Mr Ian Anderson Sickelsmith
Ms Priyanka Sinha
Ms Swetha Siringi, SRM University
Mr Balavivek Sivanantham
Mr Thomas E Sleigh
Mr Vishnu Subramani
Ryan Anthony Scott Swift
Mr Yadhu Vamshi
Mr Chris Lee Vazquez
Mr Sidharth Vohra

ISA POWID 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.

ISA67 Nuclear Power Plant Standards Committee Update

By: ISA67 Committee Chair Bob Queenan - Scientech

ISA67 is responsible for all ISA nuclear plant instrumentation and control standards and last met in June 2015 during the annual POWID Symposium and that meeting was reported on in the last newsletter. There have not been any meetings since that time. More information about the ISA67 Committee and its activities can be found at the ISA67 committee website. The group is in need of active members so please consider getting involved today!

ISA77 Fossil Power Plant Standards Committee Update

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

Hello! POWID members! The ISA77 committee last held a WebEx meeting on November 11, 2015. The meeting minutes are posted on the ISA77 committee web site. The ISA77 subcommittees continue to make progress in the revision/drafting of multiple standards. The following ISA77 subcommittees are currently resolving comments or working on document drafts;

ISA-77.00.01 Definitions and Basic Control Concepts (new document)
ISA-77.13.01 Steam Turbine Bypass Systems (in revision)
ISA-77.14.01 Steam Turbine Controls (in revision)
ISA-77.22.01 Power Plant Automation (new document)
ISA-77-42.01 Feedwater Control – Drum type (in revision)
ISA-77-82.01 SCR Instrumentation and Control Standard (in revision)

ISA77 Fossil Power Plant Standards committee is soliciting new members. The ISA77 Fossil Power Plant Standards committee was formed in 1987 to develop and maintain standards, recommended practices or technical reports on related topic to power generation. The ISA77 documents provide industry practitioners a resource for definitions, measurement requirements, design minimum requirements, references, practical industry principles, and applications practices. Currently, the ISA77 committee maintains sixteen (16) documents and is in the process of drafting two (2) new documents. The ISA77 committee consists of end users, architect engineers, equipment manufacturers, as well as vendors who are currently working in the power generation industry. For more information about ISA77, please visit the ISA77 committee website.

As a leader in instrumentation and controls for the power industry, we invite your participation in the development of the important technical standards that apply to our work. The ISA77 committee members are volunteers who comply with the ISA antitrust policies with the overall objective to draft, comment, and ballot on minimum requirements of various topics for the power industry. Most of our work is accomplished via e-mail and WebEx meetings, with perhaps one physical meeting per year in conjunction with the annual Power Industry Symposium.

Involvement as a member of ISA77 will greatly expand your knowledge of industry codes, good engineering practices, and networking through dialog with other Power experts in drafting and maintaining these ISA documents. We invite your support and involvement in this important power industry standards development. If you have any questions about ISA77, then please don't hesitate to contact either of us (Robert Hubby - bob.hubby@verizon.net or Dan Lee - dan.lee@us.abb.com.)

The next ISA77 committee meeting is scheduled for February 11th at 11:00am ET via a Live Web meeting. The ISA77 committee meetings are open to members and guests.

Two of the Best Technical Papers from the 2014 ISA POWID Symposium

During the Honors and Awards Luncheon in June 2015, Awards for two of the Best Papers for the 2014 POWID Conference in Scottsdale, Arizona was presented to:

Chuan Wang, Abhinaya Joshi, Rahul Terdalkar, Xinsheng Lou, Joe Quinn and Carl Neuschaefer of Alstom for the paper entitled "Transient Analysis of a Solar Receiver Steam Generator (SRSG) in a Solar Power Plants"

C.J. Kiger, B.J. Headrick and Z.M. Crane of Analysis and Measurement Services Corporation for the paper entitled "Integrating Electromagnetic Compatibility (EMC) into the Design Modification Process: Example Application for Spent Fuel Pool Instrumentation"

These technical papers are provided in their entirety in this newsletter for your reading pleasure.

Transient Analysis of a Solar Receiver Steam Generator (SRSG) in a Solar Power Plant

Chuan Wang, Abhinaya Joshi, Rahul Terdalkar, Xinsheng Lou, Joe Quinn, Carl Neuschaefer

Abstract

To meet the world's increasing demand for diversified renewable energy solutions, Alstom Renewable Power is expanding its power generation technologies and products from hydro and wind, to a number of new energy options, which includes solar (thermal and photovoltaic), geothermal, biomass, wave and tidal power generation.

The concentrated solar thermal power generation technologies that Alstom has developed use central tower receivers and steam generation at commercial scales. In this type of power generation plant, direct normal solar irradiance is reflected by a mirror field and used to convert solar energy through the solar receiver into thermal energy (heat). The heat can then be utilized via a) direct steam generation, or b) Molten Salt (MS) heat storage and then transferred to a water/steam process loop for steam generation. The steam is utilized in a thermodynamic cycle to produce electricity as it is used in a conventional steam power plant.

Process design and performance analyses in power plant engineering use mostly steady state model based physical calculation tools. In the design and development of a new type of solar steam generation system, the dynamic behavior needs to be well studied before its construction. In addition, the dynamic simulation tool is used in the design and verification of the control and operational strategies to ensure safe and stable operation. The process controls that require investigation include control logics for both normal and abnormal operating conditions that could lead to a need for immediate control actions or emergency shutdown. The frequency of events leading to an emergency shutdown occurrence may be low, but the importance of investigation of the consequences and their mitigation cannot be ignored.

This paper focuses on the use of power plant dynamic simulation models and their use in performing transient analyses applied to solar thermal power generation technology with direct steam generation. The objective of the transient analyses was to determine whether the designed unit can meet the operating requirements for a range of dynamic events. This paper focuses on the exploration of the transient response of the solar receiver steam generator (SRSG) in a case of emergency shutdown caused by plant blackout events. The paper presents results from a parametric sensitivity study to provide proper estimations of the sensitivity or effect on key process variables to variations in few key defined critical design parameters. The simulation results showed that for the scenarios that were analyzed, the SRSG system will remain within its mechanical design and control performance limits. This investigation using the dynamic modeling tool was very encouraging and therefore, we are continuing more transient analyses of other normal and off-normal events to further optimize the SRSG dynamic performance, and support the further development and validation of critical SRSG operation and control strategies.

Keywords: Solar Power Plant, SRSG, Transient Analysis, Plant Blackout, Parametric Sensitivity Analysis

1. Introduction

To meet the world's increasing demand for diversified renewable energy solutions, Alstom Renewable Power is expanding its power generation technologies and products from hydro and wind, to a number of new energy options, which includes solar (thermal and photovoltaic), geothermal, biomass, wave and tidal power generation.

Solar power generation is considered to be of great importance in leveraging the proportion of renewable energy production in the global power market. The concentrated solar thermal power generation technologies that are developed in the company use central tower receiver systems and steam generation at commercial scales. In this type of power generation plant, solar radiation is reflected by a field of sun-tracking mirrors, known as heliostats, to convert solar energy through the solar receiver into thermal energy (heat). The heat is then utilized via a) direct steam generation, or b) Molten Salt (MS) heat transfer fluid (HTF) with heat storage and then transferred to the water/steam side for steam generation. The steam is utilized to drive a thermal dynamic cycle to produce electricity as it is used in a conventional steam power plant. Although water/steam and molten salt are commonly used as HTF, other HTFs have been studied, e.g. air/gas (Gall et al., 2010), solid particles (Ho et al., 2009).

As the solar receiver relies on the solar irradiance as its "firing system", the solar thermal renewable power plant is facing a number of unique controls challenges that need to be handled in both the design and operations phases. One of these challenges is the heat flux fluctuation on the solar receiver caused by the movement of the sun, passing cloud (Augsburger and Favrat, 2013), changing wind velocities, etc.

Process performance designs in power plant engineering use mostly steady state model based physical calculation tools. In the design and development of a new type of solar steam generation system, the dynamic behavior needs to be well studied before its construction. One of the key reasons is to complete the design and verification of the control strategies required to ensure safe and stable operation. The process controls that require investigation include control logics for both normal and abnormal operating conditions that could lead to a need for immediate control actions or emergency shutdown. The frequency of emergency shutdown occurrence may be low but it could lead to a situation requiring significant repairs and/or lost operating hours causing considerable O&M cost and/or lost revenue, if not properly managed. Therefore, the importance of its investigation cannot be ignored.

The development of a dynamic simulation tool is important for not only the process design (Ben-Zvi et al., 2012), but also to develop operating strategies (Henrion et al., 2013; Xu et al., 2012), investigate normal and off-normal transient behaviors (Xu et al., 2011), design and testing of process control algorithms (Gall et al., 2010; Powell and Edgar, 2012), etc. for a solar thermal plant.

This paper focuses on the use of dynamic models and transient analyses applied to solar thermal power generation technology with direct steam generation. The objective of the transient analyses was to determine whether the designed unit can meet the operating requirements. The study included exploration of the transient responses of the solar power plant in case of emergency shutdown caused by plant blackout events. The paper is organized as follows. Section 2 provides an overview of Alstom's solar receiver steam generator (SRSG) process. Section 3 provides an introduction to the SRSG dynamic simulation model and discusses the Plant blackout transient event as it relates to the SRSG. The transient results and analyses of parametric sensitivity test cases are included in Section 4. Finally, Section 5 presents conclusions and recommendations for future work.

2. Solar Receiver Steam Generator (SRSG) Dynamic Simulation Model

Alstom is commercially offering two types of central tower based solar thermal power plants: 1) Direct steam production by using Solar Receiver Steam Generator (SRSG), and 2) solar thermal energy collection by using molten salt HTF in a Molten Salt Central Receiver (MSCR) with enough thermal energy storage (TES) to allow for continuous (24 hours/day) power generation from the sun and capable for dispatching. This paper focuses on the SRSG based solar power plant.

The SRSG is designed to use solar thermal energy to produce high quality steam for electricity generation. The SRSG consists of a number of circumferentially arranged solar receiver elements located on a platform atop a 200+ meters tower structure. Each receiver element consists of an Evaporator (EVAP) panel on the lower side and a Superheater (SH) panel on the upper side. The solar field with tens of thousands of heliostats concentrates solar energy onto the SRSG panels. The heat absorbed in these panels converts water into superheated steam that drives a turbine-generator to produce electric power.

As seen in Figure 1, the feed water in the steam drum is circulated by SRSG circulation pump(s) through the evaporator panels, where incident concentrated solar heat flux converts water partially into steam. The water/steam mixture coming out of the evaporator is separated in the steam drum. The separated steam is further heated in the superheater panels with concentrated solar heat flux before it is sent to the steam turbine generator (STG) to generate electricity. The water is circulated back to evaporator panels to continue the cycle. The feedwater supply is regulated to the steam drum to maintain a constant drum water level to compensate for the steam mass leaving the drum.

Alstom has developed a rigorous first principles based SRSG process simulation dynamic model to support 1) SRSG process design and mechanical stress analyses; 2) process control development and testing and 3) SRSG Control and operability analyses including, start-up, shutdown and other normal and abnormal operating modes transient analyses. The Alstom SRSG dynamic simulation model (as shown in Figure 2) includes all the major components of the SRSG and was developed using the APROS process simulation platform.

APROS dynamic simulation platform has advanced features like 6-equation modeling (separate mass, energy and momentum balance equations for both liquid and vapor phases of water/steam), large number of component libraries, controls modeling capability, advanced two-phase flow physics and metal temperature calculation. The 6-equation capability enables simulation of two-phase flow transient system. This can handle situations like steam flowing up in tubes while condensate flowing down. APROS has an advanced set of equations to predict heat transfer in single phase as well as two-phase flow including departure from nucleate boiling. Metal temperature calculation is important for systems with large length piping like that of a solar receiver in order to account for the thermal inertia.

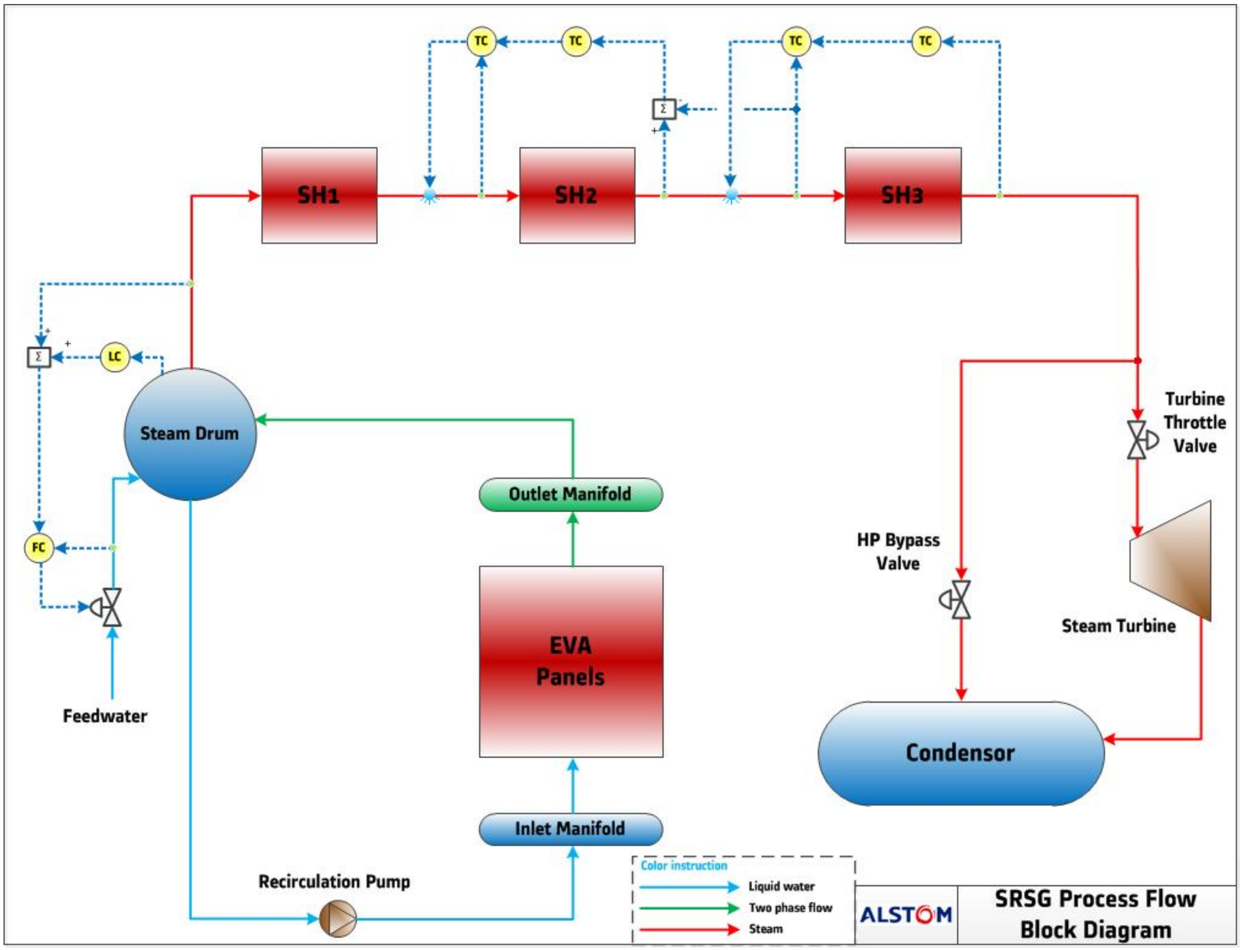


Figure 1. Block Diagram of the Solar Receiver Steam Generator

The dynamic model included the main heat absorbing components of the SRSG like evaporator and superheater panels. The model also included internal components in the SRSG like the steam drum, recirculation pumps, de-superheater, valves, drains, vents and connecting piping. The SRSG system was modelled as a lumped system in order to increase the robustness of the model during complex transient simulations. Thus, if several evaporator panels were in parallel, they were modelled as a single lumped system. All SRSG heat absorbing tube panels were modelled as wall panels with heat flux applied on just one side. Recirculation pumps were modelled in the system using actual pump curves. The pumps model also included coast down time and flow resistance to capture the behavior during a loss of power event. Similarly, all major valve specifications including valve time to closure were modelled. The model was validated with other thermal performance tools for steady state conditions at full load and part load.

The basic process controls, including three-element drum level control, pressure control, and steam temperature control, were implemented in the dynamic model. Temperature control was done primarily based on heat flux incident on different sections of the SRSG. De-superheaters were also included for finer and more rapid temperature control as required. Feed water temperature variation was included as a boundary condition. A complex heat flux model was developed to include the incident heat flux as well as radiation and convection losses on the panels. The SRSG load demand for performance was compared with available heat load from the solar field. The heat flux model included provision to selectively vary heat load on different components and sections within the SRSG in order to optimize start-ups.

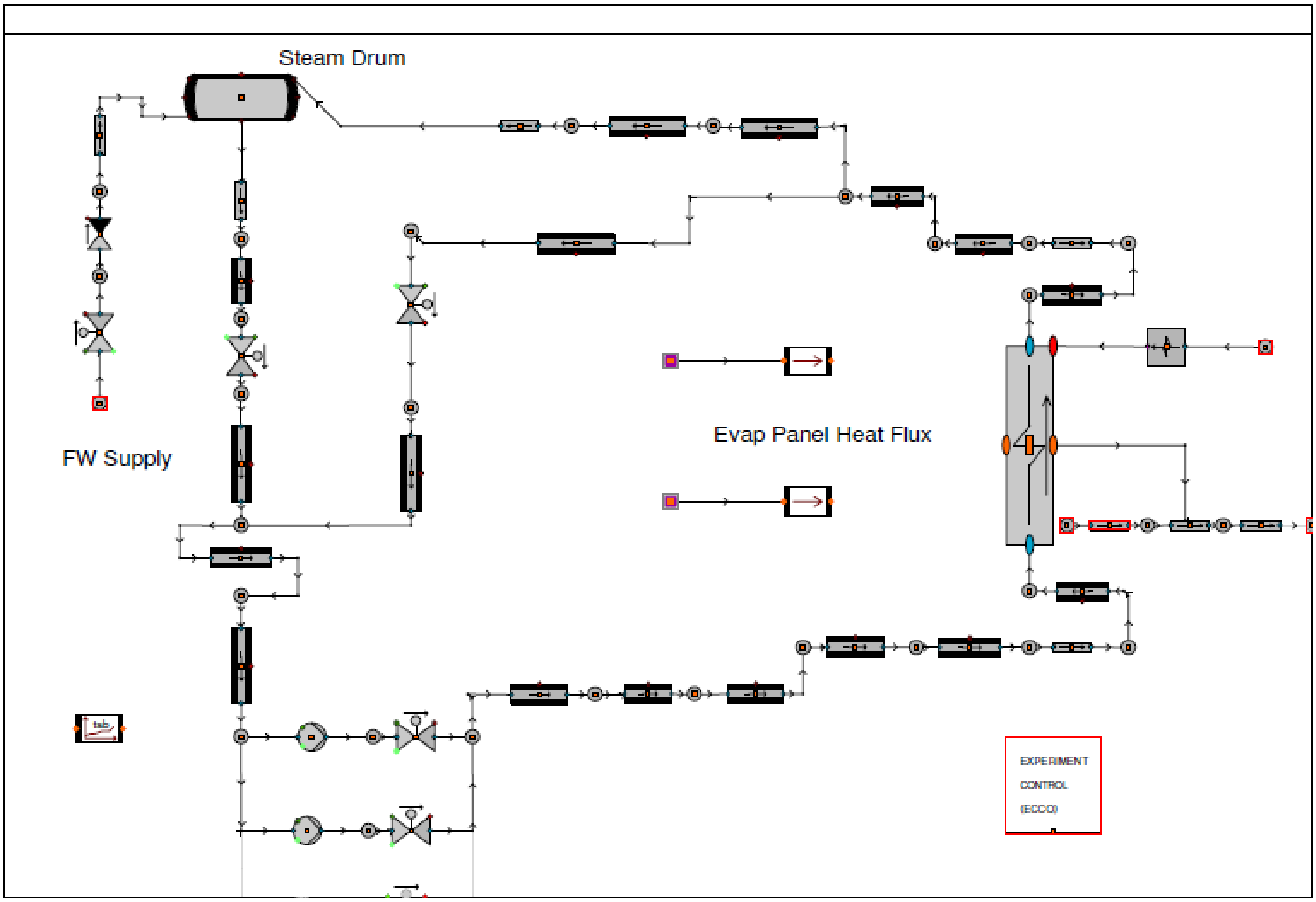


Figure 2. SRSG Dynamic Simulation Model Flow Sheet

3. Plant Blackout Event Transient Analysis

A plant blackout event is characterized by loss of electric power supply to all ancillary equipment including electrically driven feedwater pumps and SRSG circulation pumps. The objective here is to find out how the SRSG and in particular the evaporator system dynamically behaves during this loss of feedwater event in terms of level, pressure, and temperature responses while the solar field controller is defocusing thousands of heliostats from the SRSG, which takes approximately 30 seconds. To accomplish this event simulation, certain assumptions have been made in terms of initial load conditions, circulation pump coasting time, termination of feedwater supply, etc.

3.1. Plant Blackout Problem Description

Steam flows through the SRSG pressure parts which comprise of steam drum, evaporator piping, evaporator tubes, SH piping and SH tubes. The Evaporator and superheater tubes are exposed to high intensity solar heat flux during normal operation. The tubes have water/steam flowing inside which absorbs the heat incident on the tubes. In the absence of heat transfer to the fluid flowing inside the tubes, the tube metal would not be able to sustain high heat flux and its temperature would easily go beyond oxidation limit resulting in tube failure. The highest intensity heat flux is usually incident on the evaporator tubes. This is because, the evaporator tubes have water steam mixture flowing inside with very high nucleate boiling heat transfer. The evaporator flow conditions and heat flux are controlled such that all sections of the evaporator always see nucleate boiling. This flow regime is maintained using flux control, circulation pump design and FW control. The steam mass fraction coming out of the evaporator is usually kept well below 1.0.

During a plant black-out event the FW flow can suddenly stop. Also recirculation pumps are abruptly stopped due to loss of power. This can potentially stop water flow to the evaporator tubes faster than the solar field defocuses. If the water flow to an evaporator tube suddenly decreases, the steam mass fraction coming out of the tube increases and the tube heat transfer can see dry out condition (departure from nucleate boiling). Overheating of an evaporator tube at pressure can result in tube rupture failure. Tube failure and replacement necessitates immediate, extended plant shut-down, resulting in revenue loss.

Moreover, loss of FW flow can trigger a sharp drop in drum level along with potential risk of cavitation in the pumps. Dynamic modeling and simulation of the plant black-out event is important to evaluate the design and size of the equipment to sustain such events and also helps in developing process control strategy in case of a plant back-out to bring the plant to a stable condition.

3.2. Plant Blackout Event Timeline

The SRSG is assumed to be running at full mode initially. The feedwater is modeled by boundary condition with its property listed in Table 1. The pressure in the drum is about 194 bara. The drum level is controlled at the normal water level (NWL) value with the aid of a three-element controller. The main steam temperature is also maintained at its setpoint by using two stage DSH controllers.

Table 1 SRSG Full Load Initial Condition

SRSG Full Load Condition		
FW Inlet		
Temperature	^{o}C	185
Pressure	bara	205
Flow Rate	kg/s	113
Drum		
Temperature	^{o}C	359
Pressure	bara	194
Level	m	0.75
SH Outlet		
Temperature	^{o}C	560
Pressure	bara	170
Flow Rate	kg/s	115

The blackout event timeline is assumed to be as follows.

1. T = 0-10 sec. Initial full load steady state.
2. T = 10 sec. Plant blackout. Feedwater pump motors trip (see Figure 3). All circulation pump motors trip simultaneously. Condenser pump motors trip.
3. T = 11 sec. Steam turbine trips and HP bypass valve acts to limit pressure decay in the SRSG below 30 bara/min.
4. T = 11 sec. Solar field starts to defocus (see Figure 13).
5. T = 35 sec. HP bypass valve closed because condenser cannot take any more steam.

4. Simulation Results and Analyses

The intent of this parametric study was to investigate the sensitivity on the dynamic response of the SRSG process conditions to changes in key equipment dynamic parameters. Three simulation cases were analyzed to investigate impacts of: 1) rate of feedwater loss, 2) circulation pump coasting time, and 3) solar heat flux diminution time on the resulting time responses in drum level, drum pressure, and evaporator void fraction. This study was an attempt to look at what if a loss of feedwater takes a little more time, or what if the circulation pumps coasts down slower, or what if the solar field controller does not reduce heat flux in the expected time.

4.1. Loss of Feedwater

The function of feedwater supply to the SRSG steam drum is to provide water inventory for the steam generation process, and to maintain the steam drum water level at the Normal Water Level (NWL) to compensate for steam losses to the electrical generation process. Additionally, the sub-cooling effect of the feedwater directly affects the drum liquid temperature and offers a protection for the circulation pumps.

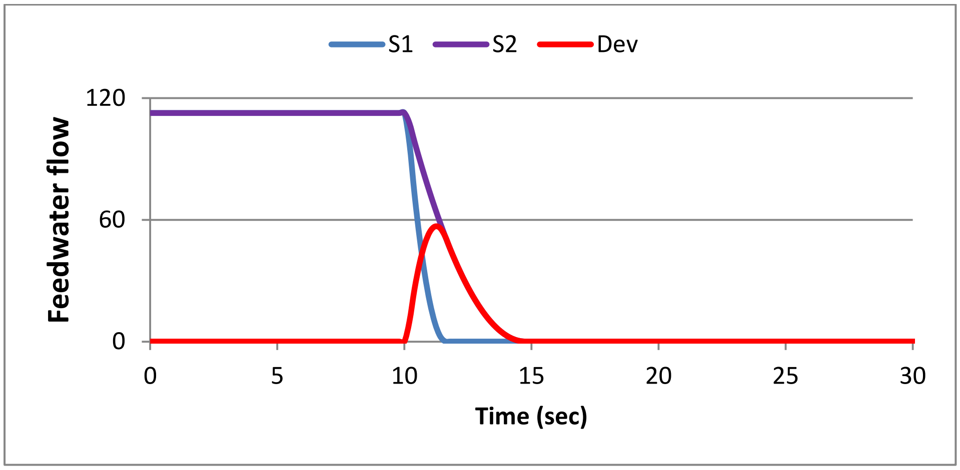


Figure 3 Feedwater Mass Flow Rates (S1 and S2)

During a plant blackout @ T = 10 sec, the motor operated feedwater pumps lose electrical power immediately, and it is assumed that the feedwater flow is lost within 2 seconds as the baseline scenario (S1). In view of the fact that the exact time for the complete loss of feedwater after the loss of power to feedwater pumps may be slightly more than 2 seconds, another scenario (S2) with time period of 5 seconds (see Figure 3 where the red trend reflects the difference between two cases) has also been considered to better understand the feedwater supply's impact on the SRSG response. In figures 3 – 7, S1 represents the baseline scenario where feedwater supply falls to zero in 2 seconds and S2 represents the second scenario where feedwater supply falls to zero in 5 seconds.

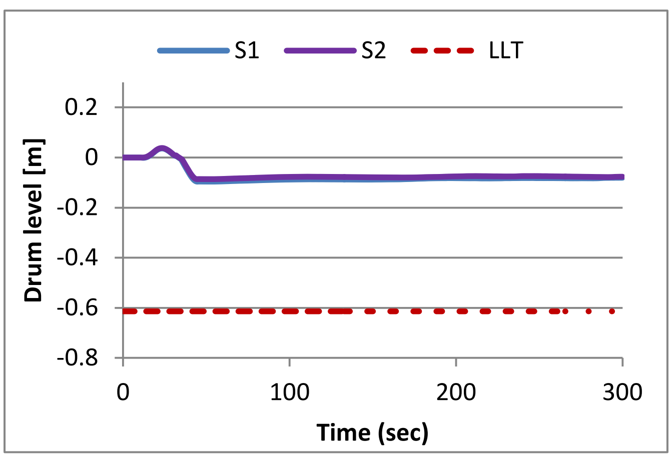


Figure 4 Drum level Response (S1 & S2)

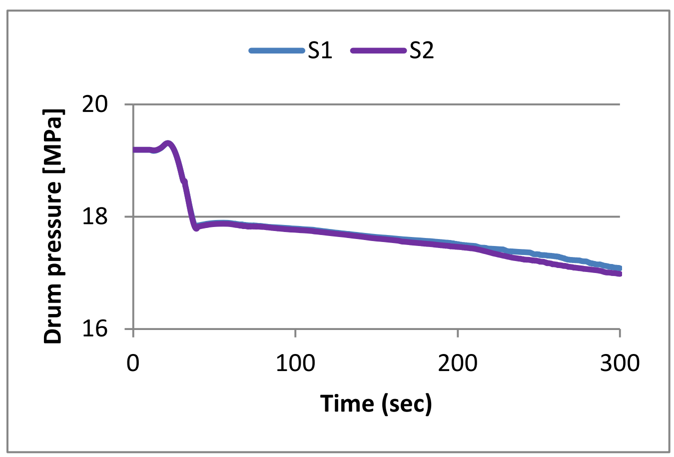
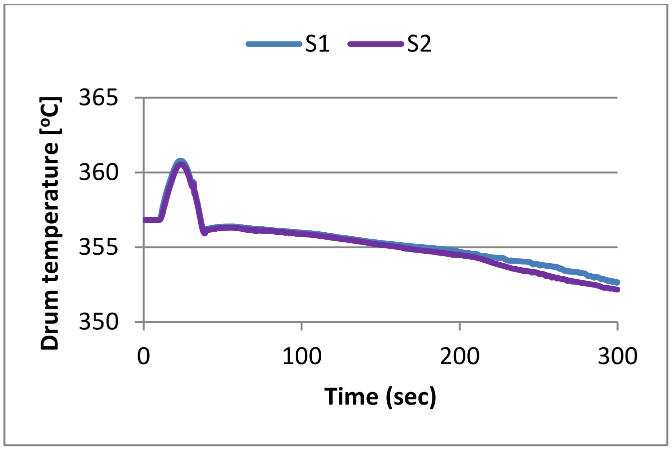


Figure 5 Drum Pressure Response (S1 & S2)



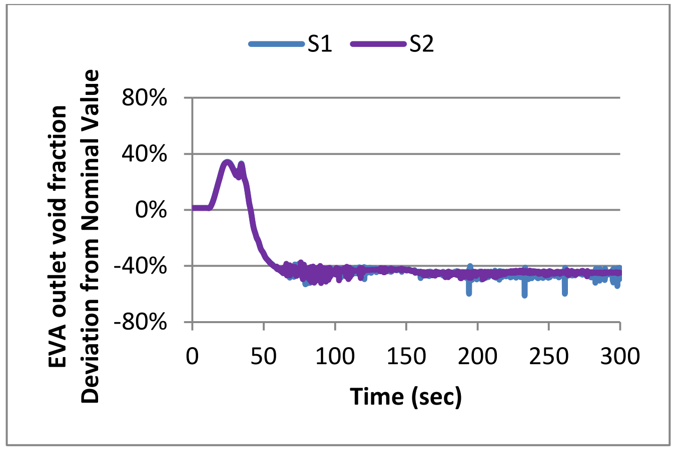


Figure 6 Drum Liquid Temperature (S1 & S2)

Figure 7 Evaporator Outlet Void Fraction (S1 & S2)

Between S1 and S2, the only difference is the time duration after which the feedwater flow rate drops to zero, while all other parameters remain the same. The feedwater flow has direct influence on the drum level. For a given steam flow, the more feedwater entering the drum, the higher the drum level will be. However, the extra amount of feedwater entering the drum (the integration of the red curve in Figure 3) is only about 1.7% of the liquid inventory already in the drum. Therefore, the simulation results between S1 and S2 in terms of drum level and drum liquid temperature are similar as seen in Figure 4 and Figure 6. As circulation mass flow rate and solar heat flux were same in scenarios S1 and S2, the simulation results for drum pressure and evaporator outlet void fraction remain almost identical as seen in Figure 5 and Figure 7.

4.2. Circulation Pump Trip Time Analysis

The circulation pumps are positioned between the steam drum and the evaporator (see Figure 1); therefore the circulation water flow through the pumps affects both drum level and evaporator steam generation. The evaporator is designed to operate such that the steam quality (or void fraction) at the outlet of the evaporator is less than 1.0. The circulation pumps trip is simulated by assuming that the pump speed reduces as a first order system. In the baseline scenario (S1), the circulation pumps trip @ T = 10 sec and the pump speed decays as a first order lag model with a time constant of 20 seconds. Another scenario (S3) was also evaluated where the pump speed coasting is considered to have a time constant of 40 seconds (see Figure 8).

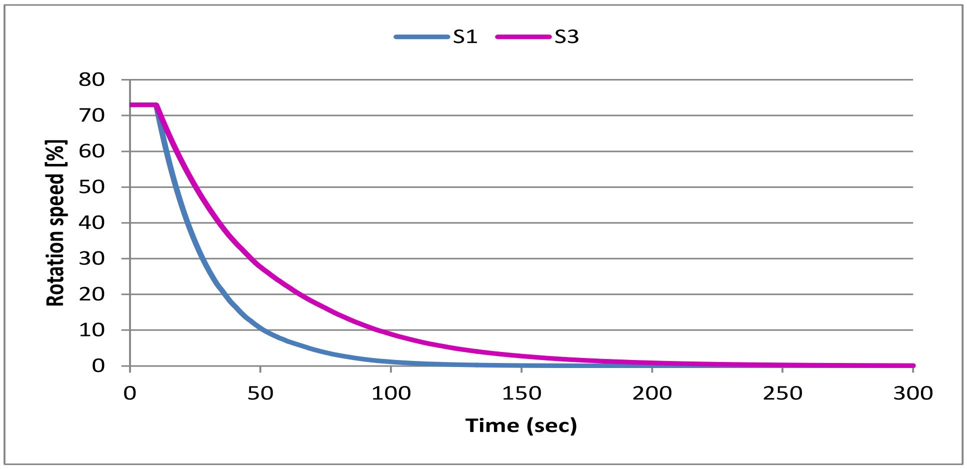


Figure 8 Circulation pump mass flow rate – S3

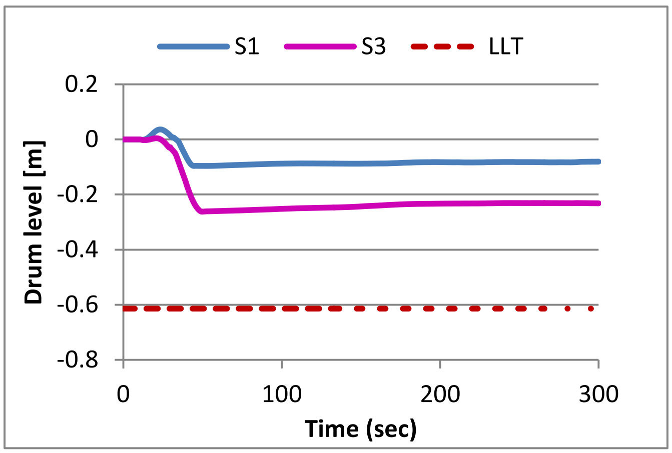


Figure 9 Drum Level Responses (S1 & S3)

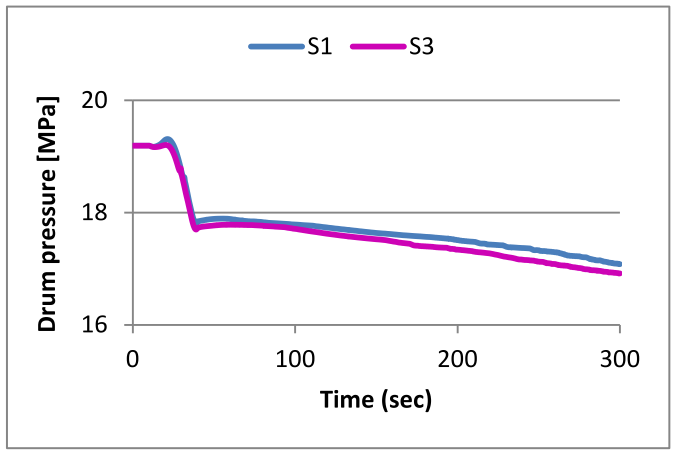
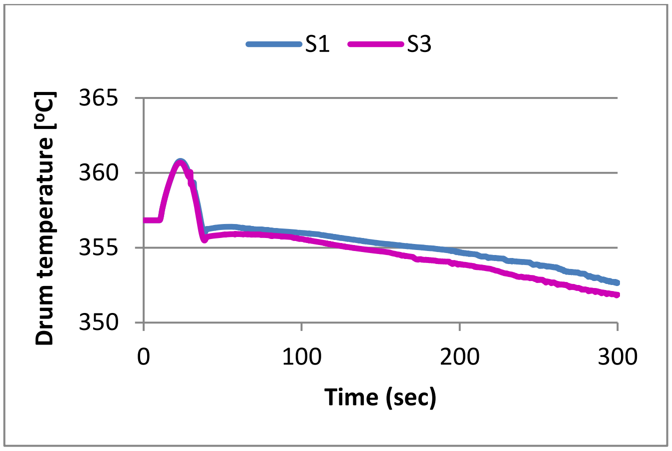


Figure 10 Drum Pressure responses (S1 & S3)

In Figures 8 – 12, S1 represents the baseline scenario where the pump speed coasts down with a time constant of 20 seconds and S3 represents the simulation scenario where the pump speed coasts down with a time constant of 40 seconds. Compared to the baseline scenario (S1), the only difference in S3 is the coast down time of the circulation pumps, while all other parameters remain the same. In case S3, the circulation flow drops to zero slower than that in the baseline case and therefore, more liquid in the drum is pumped out through the evaporator, which results in the decrease in drum level (see Figure 9). In addition, more circulation water further reduces the peak value of the void fraction at the outlet of EVA (Figure 12).



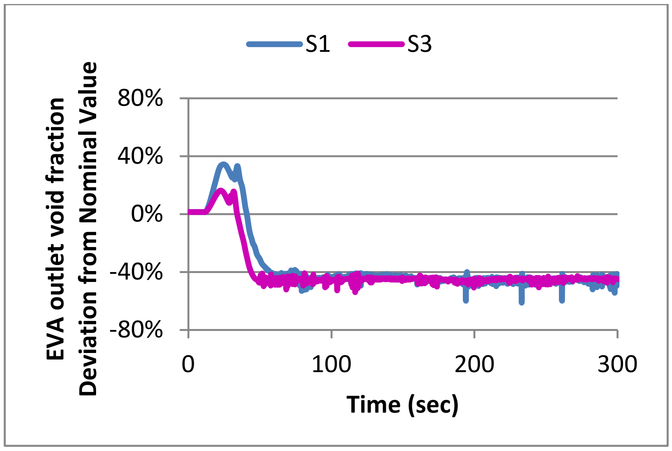


Figure 11 Drum Liquid Temperature (S1 & S3)

Figure 12 Evaporator Outlet Void Fraction (S1 & S3)

4.3. Solar Heat Flux Diminution Time Analysis

The solar heat flux absorbed by the evaporator has a direct impact on how much steam is produced, while the amount of solar heat flux on the superheater affects the steam temperature at the SH outlet. With the same circulation flow rate, the more solar heat flux applied on the evaporator, the more steam will be generated. In the baseline scenario (S1), the solar field starts to defocus 1 second later than the FWP trip, and the heat flux on both evaporator and superheater follow a diminution curve (see Figure 13). Another scenario (S4) was also evaluated where the solar field defocusing starts at the same time as S1, but the diminution time duration is stretched by 50% (see Figure 13. The amount of extra solar heat energy applied to the evaporator panels is 49.5% higher in the Scenario S4 than in the baseline Scenario S1.

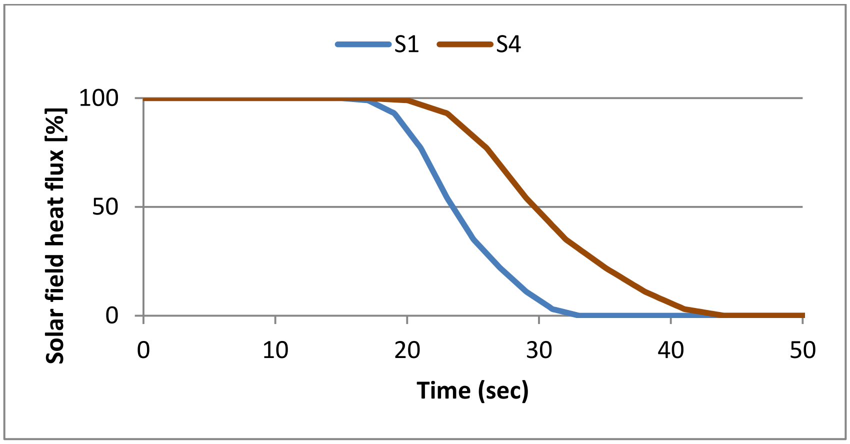
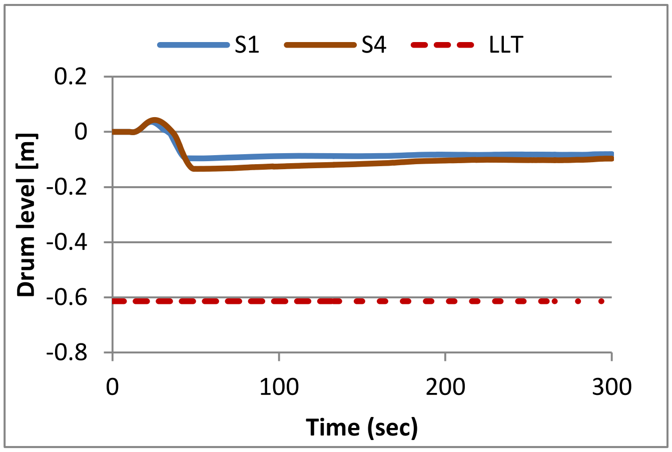


Figure 13 Solar heat flux diminution curve – S4

As more solar heat flux is absorbed by the evaporator and more steam is produced in scenario S4, the drum level (see Figure 14) is slightly lower in Scenario S4 than in S1. The extra amount of solar heat flux makes the drum pressure (see Figure 15) and temperature (see Figure 16) higher in Scenario S4 than in S1. The increase of produced steam also makes the evaporator outlet void fraction marginally higher (see Figure 17) in Scenario S4 than that in S1, which is within design limits.



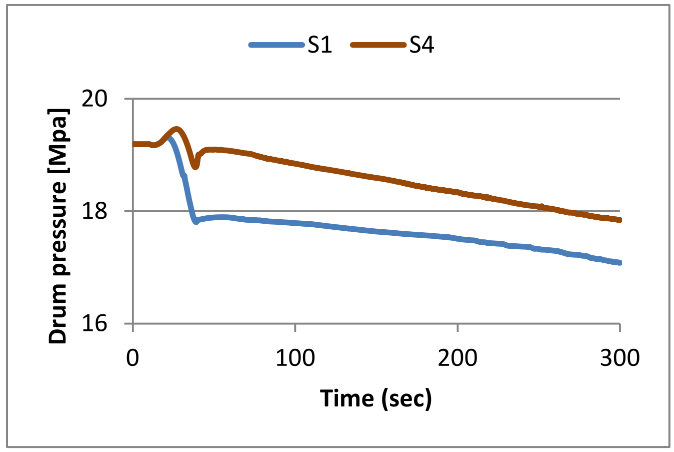
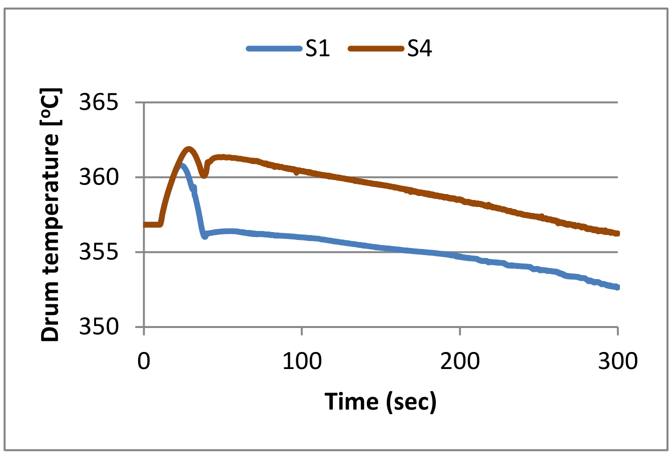


Figure 14 Drum Level Responses (S1 & S4)

Figure 15 Drum Pressure Responses (S1 & S4)



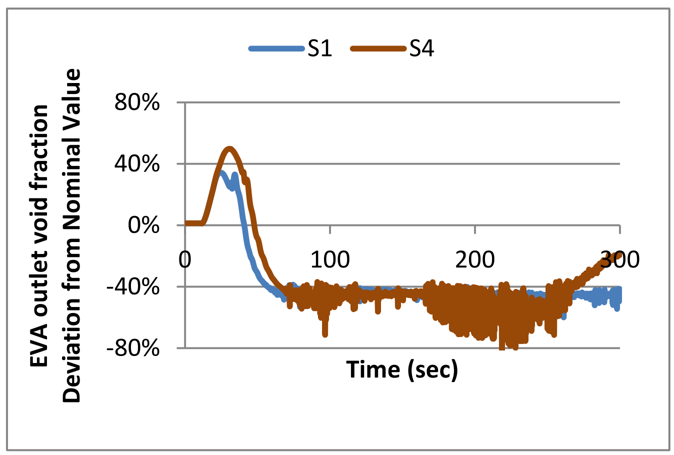


Figure 16 Drum Liquid Temperature (S1 & S4)

Figure 17 Evaporator Outlet Void Fraction (S1 & S4)

5. Summary, Conclusions and Recommendations

The dynamic simulation model based transient analyses were carried out by using a detailed SRSG model to investigate the SRSG response during a blackout event. Other external systems, e.g. feedwater supply, steam turbine, solar heat flux sources, desuperheater water supply, etc. were included in the model as boundary conditions.

Prior to the blackout event, the SRSG system is assumed to be running at the full load condition. The three-element drum level control and two-stage de-superheater spray water controllers have been implemented in the simulation model to achieve and maintain the initial steady state.

A number of cases have been simulated including a baseline case and three parametric cases to provide initial design verification information. The parametric cases include varying the time responses for loss of feedwater flow, decay of circulation flow, and diminution of solar field heat flux. All three analyzed parameters have direct or indirect impact on concerned process variables including drum level, drum pressure, and drum temperature.

The simulation results showed that for the scenarios that were analyzed, the drum inventory is adequate to withstand a blackout event and the SRSG system will remain within its mechanical and thermal performance limits.

This investigation and results provided valuable insights regarding the plant blackout event from not only the process design point of view but also from the operation and process controls design point of view. Encouraged by the results from this effort, we are continuing more transient analyses to further optimize the SRSG dynamic performance and further support the development and validation of critical SRSG operation and control strategies. Some of the operating scenarios that are being analyzed are as follows:

- Fluctuation of net solar energy absorbed by the SRSG and in particular superheat (SH) panels due to tracking inaccuracies of heliostats, changing daily normal irradiance (DNI), changing gusts of wind, passing small clouds, etc.
- Significant fluctuation in solar heat flux applied to the SRSG during cloud events, which is most severe at the beginning and the end of cloud cover over the solar field.

References

[1] Augsburger, G. and Favrat, D., Modelling of the receiver transient flux distribution due to cloud passages on a solar tower thermal power plant. Solar Energy, Vol. 87 (2013), pp. 42–52.

[2] R. Ben-Zvi, M. Epstein, and A. Segal, Simulation of an integrated steam generator for solar tower, Solar Energy, Vol. 86 (2012), pp. 578–592.

[3] Gall, J. Abel, D. Ahlbrink, N. Pitz-Paal, R. Andersson, J. and Diehl, M., Simulation and control of solar thermal power plants. In Proc. of International Conference on Renewable Energies and Power Quality, Granada, Spain, 2010.

[4] Henrion T, Ponweiser K, Band D, Telgen T., Dynamic simulation of a solar power plant steam generation system. Simulation Modelling Practice and Theory, Volume 33, April 2013, p. 2–17

[5] Ho, C., Khalsa, S. and Siegel, N., Modeling on-Sun Tests of a Prototype Solid Particle Receiver for Concentrating Solar Power Processes and Storage, In Proc. of Energy Sustainability, July 2009.

[6] K. M. Powell and T. F. Edgar, Modeling and control of a solar thermal power plant with thermal energy storage, Chemical Engineering Science, Vol. 71 (2012), pp 138–145

[7] Xu, E. Wang, Z. Wei, G. and Zhuang, J., Dynamic simulation of thermal energy storage system of Badaling 1 MW solar power tower plant. Renewable Energy, 39:455–462, 2012.

[8] Xu, E., Yu, Q., Wang, Z. and Yang, C., Modeling and simulation of 1 MW Dahan solar thermal power tower plant. Renewable Energy, 36:848–857, 2011.

Integrating Electromagnetic Compatibility (EMC) into the Design Modification Process: Example Application for Spent Fuel Pool Instrumentation

C.J. Kiger, B.J. Headrick, Z.M. Crane
chad@ams-corp.com; bradley@ams-corp.com; zach@ams-corp.com

Analysis and Measurement Services Corporation
AMS Technology Center
9119 Cross Park Drive
Knoxville, Tennessee 37923 USA
Phone: 865-691-1756

KEY WORDS

Electromagnetic and Radio Frequency Interference (EMI/RFI), Electromagnetic Compatibility (EMC), EMC Qualification Testing, Spent Fuel Pool (SFP), Digital Upgrades

ABSTRACT

The release of guidance by the Nuclear Regulatory Commission (NRC) with regard to post-Fukushima design modifications has caused the nuclear industry to implement level indication sensors in the spent fuel pool for post-accident monitoring capability. An important consideration in the design and implementation of these systems is the interaction between the sensor and the electromagnetic environment in a nuclear power plant. Even though these systems will not be relied upon for normal pool level indication, nuisance alarms or erroneous level indication resulting from electromagnetic interaction with the existing plant environment cannot be tolerated. In addition, in the event that the system is relied upon for level indication during or after an accident, it must be able to provide accurate and reliable data in the presence of electromagnetic interference (EMI).

To effectively address the Electromagnetic Compatibility (EMC) of a new system with the electromagnetic environment of a nuclear power plant, it is necessary to consider and integrate EMC throughout the entire design modification process. The appropriate EMC specifications should be provided to the manufacturer so that the design can incorporate the levels of protection and mitigation necessary to meet the EMC requirements. In addition, the implementation of the system (both the installation and the associated plant procedures) must address any shortcomings identified during EMC

qualification testing and take the appropriate measures to prevent future EMI. These concepts will be presented along with examples of recent activities associated with spent fuel pool instrumentation enhancements at various nuclear power plants.

INTRODUCTION

After spent nuclear fuel assemblies are removed from a plant's reactor, they are maintained under water in a spent fuel pool prior to long-term storage in dry casks or a permanent storage facility. The water in the pool serves to maintain the temperature of the spent fuel assemblies within specified limits and to shield the surrounding environment from radiation emitted by the fuel. It is well-known that the Zircaloy cladding used in nuclear fuel assemblies, when oxidized by steam, produces combustible hydrogen. This can occur if the assemblies are exposed to air in either the reactor core or the spent fuel pool. Such an event took place at the Fukushima Dai-ichi nuclear power plant in March 2011. During the crisis surrounding Units 1, 2, and 3, plant operators speculated that the water levels in at least one spent fuel pool had dropped, exposing the spent fuel assemblies to oxygen and leading to hydrogen production as well as spent fuel overheating and radiation leakage. Though it was later determined that the spent fuel was sufficiently immersed and that the hydrogen was actually produced in the reactor cores of the distressed units, the lack of spent fuel pool level indication forced emergency responders to divert significant time and labor to assessing a spent fuel pool problem that ultimately did not exist.

Following the events at Japan's Fukushima Dai-ichi Nuclear Power Plant in March 2011, the Nuclear Regulatory Commission (NRC) is emphasizing the need for improved monitoring of spent fuel pools. An NRC task force [1] found that:

> *"The lack of information on the conditions of the fuel in the Fukushima spent fuel pools … contributed to a poor understanding of possible radiation releases and to confusion about the need and priorities for support equipment. The Task Force therefore concludes that reliable information on the conditions in the spent fuel pool is essential to any effective response to a prolonged station blackout or other similarly challenging accident."*

The event at Fukushima Dai-ichi has served to heighten awareness in the nuclear industry that existing instrumentation cannot adequately inform plant operators of spent fuel pool conditions outside normal, and slightly off-normal, conditions. As such, the NRC has issued Order EA-12-051 [2], entitled "Order to Modify Licenses with Regard to Reliable Spent Fuel Pool Instrumentation", which requires, among other things, all licensees have wide range level indication equipment capable of monitoring the spent fuel pool water level continuously through three distinct regimes of operation (as shown in Figure 1).

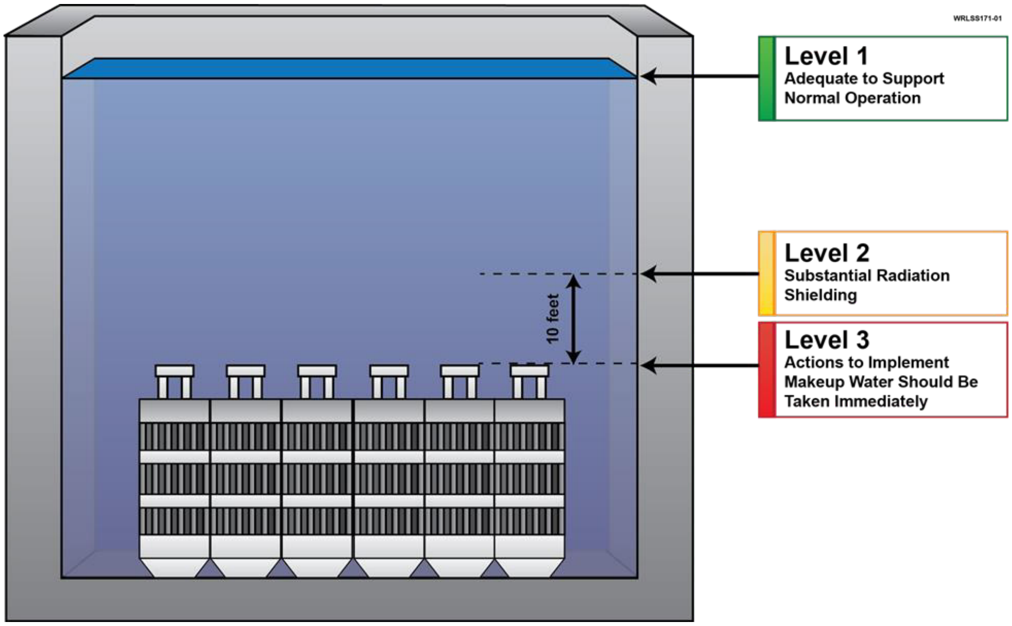


Figure 1. Required Level Monitoring in Spent Fuel Pools, per NRC Order EA-12-051

As with any plant upgrade, an EMC assessment of the installed equipment and the electromagnetic environment in which it will be installed is essential to ensuring that safety and efficiency are maintained.

According to the Nuclear Regulatory Commission (NRC) Regulatory Guide 1.180 Rev. 1, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems" [3], plants must take steps to ensure that there are no incompatibilities prior to installing new or upgraded systems, specifically safety-related systems. Typically, specifications for new equipment to be installed in a nuclear power plant require the Original Equipment Manufacturer (OEM) to quantify the electromagnetic emissions and susceptibility of the equipment prior to installation. This evaluation is performed using currently available test standards before equipment is brought on-site. Failure to properly qualify equipment for the plant's specific electromagnetic environment (EME) can lead to the following issues:

- Last-minute, expensive changes to the new equipment
- Re-engineering of the plant environment to re-locate equipment
- Electromagnetic Interference (EMI) between new and/or existing plant equipment
- Erratic, unplanned behavior of new and/or existing equipment

ADDRESSING EMC CONCERNS

The biggest challenge facing system and design engineers with respect to EMC is that it is not universally understood. Oftentimes, EMC practices are based on preconceived notions and secondhand information handed down over time, as opposed to an understanding of the phenomena involved. This lack of understanding can lead to the perception of EMC as a "black art," which is to be integrated into the design process only when time permits. However, the reality is that EMC is a systematic process which becomes progressively more difficult and expensive to accomplish the further along a project progresses. To achieve the best possible outcome in terms of both schedule and cost, EMC should be considered in all phases of the design and construction process as shown in Figure 2.

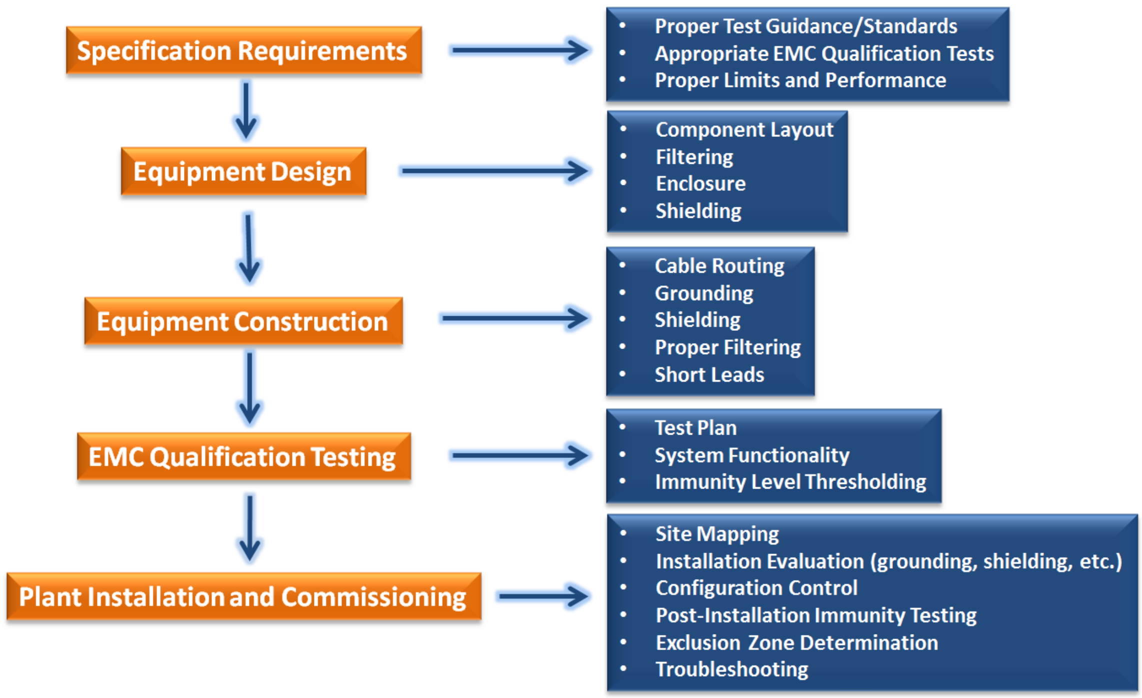


Figure 2. Process for Integrating EMC in the Design Modification Process

Specification Requirements

One of the most important steps in the EMC process is to ensure that the requirements placed on the system with respect to EMC are adequate for the intended installation. This can be challenging for system and design engineers when considering the current state of EMC guidance for the nuclear industry. The two documents accepted by the NRC are NRC Regulatory Guide 1.180 and EPRI TR-102323 Revision 1. However, EPRI TR-102323 is now in Revision 4. Understanding the commonalities and differences between the EPRI revisions and the NRC guidance regarding the test methods, acceptance limits, and applicability can be a difficult and complex task. However, selecting the necessary and/or appropriate tests to ensure that the system does not generate excessive electrical noise (emissions) and can withstand the EMI expected at the point of installation (immunity) will be key to the successful implementation of any upgrade. For instance, the fuel handling bridge has been found to be a source of excessive emissions and may not always be bounded by the electromagnetic environments used to develop the original acceptance levels for emissions and/or immunity.

Within the bounds of NRC and EPRI guidance, there are several areas within EMC qualification testing that can be customized to suit a particular plant's needs. (Some utilities have gone as far as preparing their own guidance documents to address EMC.) The first area is the frequency ranges of the various tests. For example, NRC Regulatory Guide 1.180 does not require testing for electric field emissions and immunity above 1 GHz, but does make a provision for testing in this frequency range. If a site uses Wi-Fi or other wireless devices, allows cell phones on-site, or includes PC based systems, then it is critical to understand and utilize the additional provisions and test above 1 GHz to ensure that EMC is maintained. In addition to the frequency range, the acceptance levels can also be increased or decreased depending on the plant conditions expected at the point of installation. However, care must be taken to ensure that the environment is properly characterized and an engineering justification prepared before relaxing any emissions or immunity limits. This is particulary important for spent fuel pool modifications because there will be numerous areas impacted by the installation of the equipment besides just the spent fuel pool area.

Another important consideration that must be included in the design specification deals with addressing the various aspects of immunity testing. The appropriate levels based on the plant environment and system characteristics should be clearly spelled out in the design requirements. An often overlooked portion of the design preparation is the specification for the acceptable level of susceptibility. There must be a clear understanding of the acceptable performance of the equipment during and after it is exposed to EMI. For instance, should a system be able to maintain stable operation during an EMI event or is deviation acceptable as long as the system recovers once the EMI is removed? Acceptable tolerance bands for analog signals should be stated, as well as a specification for any digital behavior. The design requirement should clearly state the level of immunity which the system must have to the various kinds of EMI. These acceptance criteria are based on the needs and requirements of the site and are not provided in the NRC or EPRI guidance documentation.

Equipment Design

There are numerous considerations with regard to addressing EMC during the design of equipment for a nuclear power plant. These include evaluation of component functions, specifications, and operational configuration. Some of the critical items for review with respect to EMC are:

- Power Supplies
- Power Filtering
- System Wiring Types
- System Inputs/Outputs
- Input/Output Filtering
- Shielding
- Enclosure Material and Construction
- PCB Layout
- Operating Frequencies

One of the important concepts in the design of a system with respect to EMC is minimalism. This includes not adding more capabilities than are necessary and maintaining clock speeds that are adequate for the operation of the equipment and not selecting clock speeds that are too high. For instance, a tank level monitor does not need to be able to determine the level at microsecond intervals. Doing so may generate electrical noise and/or expose vulnerabilities of the system.

Good engineering practices with respect to EMC should also be utilized such as the use of filter capacitors when necessary. Oftentimes, the addition of a simple filter capacitor to the output of a switching power supply can make the difference between passing and failing an emissions test. Likewise, arrangement of shielding materials and proper design of low impedance return paths for EMI currents can mean the difference between a smooth EMI qualification and a costly redesign.

Once the entire system design is completed, there should be a review of the system by someone knowledgeable in EMC. Ideally this would be performed throughout the entire design process by the engineer in charge. However, in the event that the engineer in charge does not have a working knowledge of EMC best practices, a second independent review of the design, even at completion can help ensure that sufficient EMI mitigation practices have been implemented.

Equipment Construction

One of the most overlooked areas of EMI control is the proper construction and wiring of equipment. This is often performed without regard to EMC, focusing instead on ease of installation and wire routing convenience. The tradeoff of wiring convenience is that noise from any device in the system can couple to other devices and/or radiate from the system enclosure. A few hours planning the placement of components and the routing of signal and power conductors can save significant time and money in troubleshooting later. This process carries a strong analogy to concepts that are employed for the placement of components and routing of traces for printed circuit boards, and can attain many of the same benefits in terms of EMI control.

During equipment construction, the following checklist can be very helpful in capturing and preventing simple EMI issues:

- Minimize mixing of input and output wiring
- Segregate known EMI offenders such as relays from sensitive equipment
- Separate power and signal cables
- Do not tie wrap cables together
- Utilize proper filtering techniques, maintain separation of filter inputs and outputs
- Use twisted pair cables, even shielded twisted pair if appropriate – avoid single conductor cables
- Route signal and returns together to avoid creating antennas which can radiate or receive EMI
- Trim excess wire lengths as opposed to leaving excess in the bottom of cabinets or enclosures
- When cables cross over one another, do so at 90 degrees to minimize crosstalk.

Separation and segregation of cables by signal type is a common theme in this checklist. Because coupling is a function of distance, any separation that can be maintained will help attenuate EMI coupling. After the equipment is constructed, as-built precompliance testing can be performed at the manufacturing facility. This testing can provide preliminary insight into the EMC performance of the equipment, and suggest areas where improvement is needed before the system is sent to a laboratory for qualification.

EMC Qualification Testing

Even after the candidate system has been constructed, preparation for qualification testing is not complete. Prior to shipping the equipment to an EMC lab, (depicted in Figure 3) the test plan should be evaluated and ensured to be consistent with the chosen limits, procedures, and acceptance criteria as it will serve as the governing document for all testing. Next, suitable lengths of representative cable should be procured and clearly labeled to save set up time at the test facility. Cabling should be as close as possible to what will be used in the actual installation. It is counter-productive to send individual unshielded conductors for I/O cable if the installation will utilize twisted, shielded conductors. The cost savings in materials could result in excessive troubleshooting costs for a problem that will not be an issue in the plant installation. Monitoring and support equipment for the system under test should also be evaluated and should be suitable for the device under test. The support equipment should be located external of the shielded test enclosure to prevent it from impacting the test results.

During the qualification testing it is important that the test methods be strictly adhered to and any deviations be documented in the final report. Any configuration changes to the equipment that are necessary for it to comply with the test requirements shall also be documented and included in the design for the installation into the plant. The performance of the equipment shall be monitored and any test data included with the final report. In instances where the equipment could not be modified to increase its immunity to RF and other sources, an evaluation can be made regarding the use of exclusion zones around a particular piece of equipment. This could be used to limit the use of radios/transmitters, maintain door closure, and prevent the performance of welding in the vicinity of the equipment while it is in operation.

The qualification of spent fuel pool instrumentation will be particularly challenging because the system can span several locations separated by hundreds of feet. The traditional approach is to qualify a complete system with all components tested at the same time. This approach can be applied to a cabinet, panel, or individual modules being installed in a plant. However, for immunity testing of the spent fuel pool instrumentation system, it would be beneficial to test the components for each individual location. This will ensure that the components are subjected to the proper level of EMI and also simplify the identification and resolution of any vulnerabilities. In addition, it would be best to test the components with any panel doors open and without the cables installed in conduit. By removing these additional layers of protection, the system can be fully exercised for vulnerabilities. They can be implemented if the system exhibits susceptibility to EMI.

Figure 3. Qualification Testing in an EMC Laboratory

Plant Installation and Commissioning

The final and most critical portion of the EMC process for a plant upgrade is the installation of the system into the power plant. For a spent fuel pool level indication system, the system will often be retrofitted into the plant. This will often result in the installation of new conduit and cables but may reuse some of the existing plant infrastructure. Installing new conduit and cables dedicated for the spent fuel pool system will be the optimal choice for mitigating EMI. The cables can be routed away from sources of EMI and the conduit will provide a level of shielding and isolation. If the system will reuse existing cables and cabinets then additional care and attention to detail will be necessary to minimize the potential for EMI.

There are several considerations for maintaining EMC whether installing new cables or reusing existing cables. One wiring practice that is commonly a cause for concern is the handling of shield drain wires. The length and routing of the shield drain wire has a significant impact on the effectiveness of the shield. Oftentimes, drain wires are daisy chained together, or brought to a terminal block with a long wire then running to instrument ground. This can result in a drain wire that can be in excess of 6 feet in length. For frequencies greater than several kHz, this shield connection will not provide adequate impedance control, allowing EMI to couple to the signal leads. Typical transients in a power plant can have frequency content up to several hundred MHz. The drain wire should be kept as short as possible using a low impedance connection directly to a ground bus bar or to cabinet steel (if the cabinet steel is the EMI ground reference). The best practice is to route a ground bus bar next to the terminal block and connect the shield drain wires directly to the bus bar.

Several instances of poor wiring practices are shown in Figure 4. In the left of the photograph, the shield wires have been connected to an instrument ground bus bar that is isolated from the cabinet steel. The instrument ground bus bar is connected to plant steel underneath the cabinet but for EMI, this results in a high impedance connection to its ground reference. A better practice is to connect the instrument and safety ground (plant ground) directly in the cabinet to prevent a voltage potential between the two different grounds. (The recommended grounding practice of the manufacturer should take precedence. One instance where common ground connections may not be desired would be when the cabinet grounds are daisy-chained together and the current flow through the grounding system may not be known.) The presence of a voltage potential between the safety and instrument ground will allow for current flow and could result in EMI. The photograph on the right of Figure 4 shows several instances of wiring practices that expose a system to the potential for EMI. They include the following:

- The shields are daisy-chained instead of directly connected to ground
- The cables are tie-wrapped together rather than being loose and separated
- The shields were stripped back at the cabinet entrance and the drain wires ran parallel to the signal leads all the way to the terminal block rather than maintaining the shield up to the terminal block
- The signal leads are separated for several inches away from the terminal block rather than being twisted all the way to the terminal block

There are several other good installation practices that can be employed to minimize the effects of EMI. For instance, the internal cables should be routed next to the cabinet steel to reduce their ability to act as antennas to receive and/or radiate EMI. To prevent unused cables from radiating EMI into a cabinet they should be properly terminated and/or tucked back into the conduit and not allowed to enter the cabinet. Other installation practices for grounding, shielding, and cable routing can be found in the IEEE 1050 standard [4], EPRI TR-102323 Revision 3 [5], and the EPRI TR-102400 Volume 2 [6].

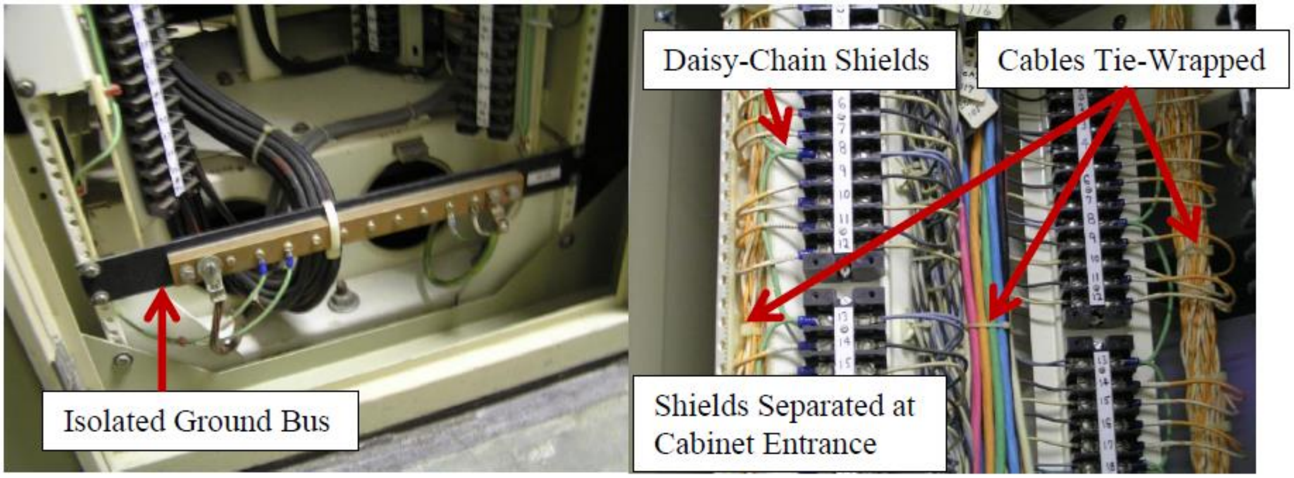


Figure 4. Improper Cabinet Wiring Practices

EXAMPLE OF SPENT FUEL POOL EMC EVALUATION AND TESTING

Recently an EMC evaluation was performed for a nuclear power plant in support of the installation of components for the spent fuel pool level indication system. The purpose of the evaluation and testing was to provide an understanding of the electromagnetic environment where the supplemental level instrumentation devices were being installed and to determine whether or not there will be a significant risk of EMI after the installation of the spent fuel pool system.

The evaluation consisted of three separate activities. The activities involved reviewing the EMC test plan for the spent fuel pool instrumentation, measuring the electromagnetic emissions at various locations in the nuclear power plant, and performing an overall evaluation of the system taking into account the results of the EMC testing and site survey as well as the planned installation practices for the level indicator and electronics. The first step of the evaluation was to ensure that the system was being subjected to the appropriate EMC qualification tests and levels. Because the system is comprised of many different components, some of which are commercial-off-the-shelf items, the site only required EMC testing on the components which did not have any previously documented qualification testing. The previous qualification testing was not necessarily performed to nuclear standards. For instance, the level indication sensor was qualified to commercial International Electrotechnical Comission (IEC) standards. These standards test to radiated electric fields, such as those generated by wireless devices, to 3 V/m. The EPRI and NRC guidance both specify this testing to levels of 10 V/m. Therefore, the known level of immunity of the system is much lower which means that the radio exclusion distance established around the system would need to be larger. For the components of the system that were to undergo EMC qualification testing, the full suite of tests (both emissions and immunity) would be applied to the system according to the EPRI guidance. Improvements to the test plan were recommended to ensure the testing was representative of the plant installation.

The second phase of the evaluation was to perform site mapping at the nuclear power plant to characterize the various areas of the plant impacted by the installation of the spent fuel pool system. Site mapping consists of measuring radiated emissions (in the air) and the conducted emissions (on the cables). Since the cables for the new system had not yet been installed, only radiated emissions were captured. The radiated emissions tests were performed based on guidance from EPRI TR-102323 Revision 3 using the RE102 test method of MIL-STD-461E. The RE102 test method from MIL-STD-461E characterizes the electromagnetic environment by measuring and recording the amplitude of the electric fields using several antennas covering different frequencies. This particular testing used four antennas to cover the frequency range of 10 kHz to 10 GHz. Radiated emissions were measured at five (5) areas identified by coordination between plant and AMS personnel. Testing locations were identified in the main control room (display), 2 locations in the spent fuel pool (sensor), 2 elevations of the reactor building (backup electronics and backup display) and one elevation of the auxiliary building (primary electronics). These are the five areas where components of the spent fuel pool level indication system will be permanently installed. While some of the emissions exceeded the EPRI TR-102323 Plant Composite Limits, none of the recorded emissions exceeded the EPRI TR-102323 Allowable Plant Level of 4 V/m (132 dBμV/m). The maximum emissions identified on-site were from wireless communication devices in the power block, detailed in Table 1. These emissions were measured and were well below the 4 V/m threshold since they were not being operated within close proximity of the testing but were being used in other areas of the plant to support outage activities.

Table 1. Maximum Emissions Identified During EMC Evaluation

Device	Frequency	Magnitude of Emission (dBµV/m)	Magnitude of Emission (V/m)	EPRI Plant Composite Level at Emission Frequency (dBµV/m)	Location
Plant Radios	450 MHz	82.6	0.014	72.5	Spent Fuel Pool
RadioCom TR-700	550 MHz	83.6	0.015	71.9	Spent Fuel Pool
RadioCom TR-700	675 MHz	85.8	0.020	71.3	Spent Fuel Pool
Plantronics CT10	900 MHz	88.0	0.025	70.4	Spent Fuel Pool
AT&T CL81211	1.9 GHz	95.3	0.058	N/A	Spent Fuel Pool
Motorola MC75A0	2.4 GHz	95.6	0.060	N/A	Spent Fuel Pool

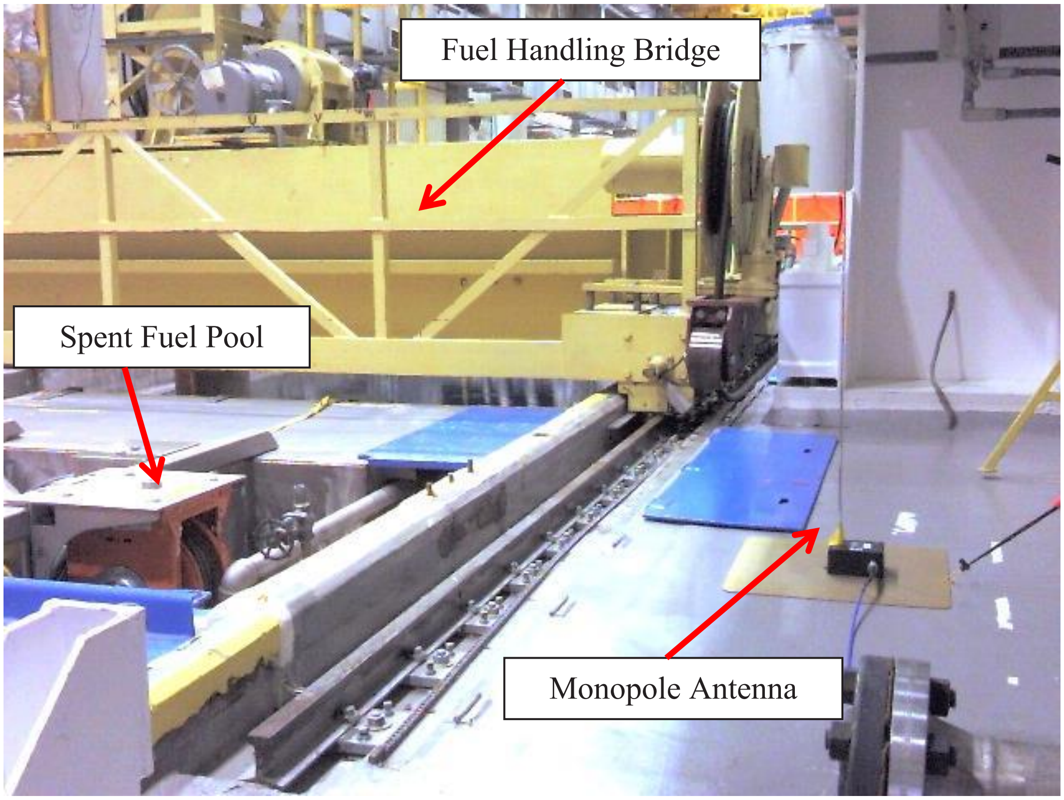


Figure 5. EMC Emissions Testing Next to the Spent Fuel Pool

Currently, the final components of the system are undergoing EMC testing and the final drawings are being put together to outline the installation of the system with respect to EMI. Once these two items are completed, an overall evaluation of the system will be performed to outline the steps necessary to ensure EMC. This will include recommendations for the establishment of radio exclusion zones, recommendations regarding grounding and shielding of the system, and recommendations for power routing and filtering.

CONCLUSION

Designing for EMC is a critical step in the process of ensuring that equipment can operate in the plant's electromagnetic environment. The most efficient way to address EMC concerns is continuously throughout the entire equipment design and installation process. This includes ensuring that the proper EMC requirements are part of the design specifications, that the design engineers understand and incorporate EMC concepts into the equipment design and construction, that the qualification testing follows the appropriate testing methodology, and that the plant installation follows the industry recommendations and guidance with respect to EMC. By addressing EMC during the entire design modification process, the nuclear industry can move towards more robust and reliable spent fuel pool instrumentation.

REFERENCES

1. "Recommendations for Enhancing Reactor Safety in the 21st Century." The Near-Term Task Force Review of the Insights from the Fukushima Dai-ichi Accident. U.S. Nuclear Regulatory Commission. July 2011.

2. "Issuance of Order to Modify Licenses with Regard to Reliable Spent Fuel Pool Instrumentation." EA-12-051, U.S. Nuclear Regulatory Commission. March 2012.

3. "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems." U.S. Nuclear Regulatory Commission Regulatory Guide 1.180 Revision 1. October 2003.

4. "IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations. 1996 Edition" Institute of Electrical and Electronic Engineers. 1996.

5. "Guidelines for Electromagnetic Interference Testing of Power Plant Equipment, Revision 3 to TR-102323." EPRI, Palo Alto, CA: 2004. 1003697.

6. "Handbook for Electromagnetic Compatibility of Digital Equipment in Power Plants." EPRI TR-102400-Volume 2, Palo Alto, CA: 1994.

7. "Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment." MIL-STD-461E, US Department of Defense, August 1999.

International Society of Automation
67 T.W. Alexander Drive
P.O. Box 12277
Research Triangle Park, NC 27709

Nonprofit Org.
U.S. Postage
PAID
Raleigh, NC
Permit #1461