**Director's Message**

By Brad S. Carlberg, P.E.
Prime Controls – Metairie, LA

Honorable Members of PUPID,

Well, it is already the third week of August and I am in the midst of commissioning a Hurricane Mitigation project here in Belle Chasse, Louisiana (on the West Bank across the river from New Orleans).

Just like always, we still need a Director-Elect, and a symposia coordinator. The Director-Elect will train with me in 2012 and take over as Director for the 2013/2014 biennium. If you can only do it for a single year, then we can look at single terms. In return for the work, you'll get your ISA Spring and Fall Conference expenses paid by the division.

This September, the ISA Automation Week 2012 will be at the Orange County Convention Center in Orlando, Florida. If you’ve thought about getting involved with a technical conference and/or writing a paper, this is for you. You can bring the family to play at Disney World while you see all of the latest instrumentation and controls at the Fall conference.

Our division membership has increased from 450 to 451 members with 4 new division members since February. The membership has stayed nearly constant since last January. Welcome to all of you new members!

I am also pleased to be able to include Saul Mtakula’s paper and see his presentation for “Filtrate Balance on O2 Delig Unit via a Multivariable LQG Controller” from the PacWest 2012 Conference last month in Jasper, Alberta. (Saul presented immediately following last Rick Van Fleet’s presentation that was included in the Spring 2012 newsletter.)

I hope it is an encouragement to you to become more involved with the Division and to enroll more members from the great international pulp & paper community.

Please do not hesitate to contact me at either (251) 454-1200 or brad.carlberg@bsc-engineering.com to discuss how you can help PUPID.

Do feel free to forward the Newsletter to your friends and colleagues who may have an interest in it.
### Tuning Tip:

**ABSTRACT**

*This Tuning Tip was excerpted from “” by from. ISA Members can download this paper FOR FREE from the ISA website.*

### Calendar of Events

Get a quick overview of the ISA PUPID events for 2011 by going to the Calendar at: [http://www.isa.org/~pupid/2012_PUPID_Calendar.htm](http://www.isa.org/~pupid/2012_PUPID_Calendar.htm)

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<th>Event</th>
<th>Date</th>
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<tr>
<td>2012 Pan Pacific Conference</td>
<td>11/20/2012 to 11/22/2012</td>
<td>Hotel Horison</td>
<td><a href="http://www.reptech2012.org/">Bandung, West Java Indonesia</a></td>
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<tr>
<td>2012 TAPPI PEERS Conference</td>
<td>10/14/2012 to 10/18/2012</td>
<td>Marriott Savannah Riverfront</td>
<td><a href="http://www.tappipeers.org/">Savannah, GA USA</a></td>
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<tr>
<td>2012 BLRBAC Fall Meeting</td>
<td>10/1/2012 to 10/3/2012</td>
<td>Crown Plaza Hotel Atlanta Airport</td>
<td><a href="http://www.blrbac.org">Atlanta, GA</a></td>
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<td>2012 China Paper Technical Conference</td>
<td>9/10/2012 to 9/12/2012</td>
<td>Sheraton Shanghai Hongqiao Hotel</td>
<td><a href="http://www.chinapaperexpo.cn/">Shanghai</a></td>
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<td><strong>2012 ISA FALL LEADERS MEETING</strong></td>
<td><strong>Saturday, Sept 22 2012 and Sunday, Sept 23 2012</strong></td>
<td><strong>ISA AUTOMATION WEEK 2011</strong></td>
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<td><strong>ISA AUTOMATION WEEK 2011</strong></td>
<td><strong>Monday, Sept 24 2012 through Thursday, Sept 27 2012</strong></td>
<td><strong>ORANGE COUNTY CONVENTION CENTER</strong></td>
<td><strong>ORLANDO, FL</strong></td>
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LISTEN TO THE TECHNICAL SESSIONS FROM ISA AUTOMATION WEEK 2011

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<th>Wireless Measurement and Control Opportunities Tutorial</th>
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<td>Session Moderator: Tom Fillers; Filltronic Services; Mobile, AL</td>
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<td>AUDIO  POWERPOINT  PAPER  Greg McMillan</td>
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<tr>
<th>Wireless Track</th>
<th>Wireless, CyberSecurity, &amp; Control Systems</th>
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<td>Tuesday Session 2 (1:30 pm-3:00 pm)</td>
<td>Session Moderator: Kenneth R. Williams; Instrument Control Specialist Sr. Alabama Power Company Barry Generating Plant; Bucks, AL</td>
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<td>AUDIO  POWERPOINT  PAPER  Wireless In-Core Detector Instrumentation (WIDI) - Jorge Carvajal Westinghouse Nuclear</td>
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<th>Wireless Track</th>
<th>Large Scale Sensor Networks Tutorial</th>
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<tr>
<td>Tuesday Session 3 (3:30 pm-5:00 pm)</td>
<td>Session Moderator: Will Kiser, E&amp;I Resource Leader; Hargrove Engineers &amp; Constructors; Mobile, AL</td>
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<td>AUDIO  POWERPOINT  PAPER  Large Scale Sensor Networks Mark Nixon - Emerson</td>
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<th>Installation, Operations, and Maintenance Track</th>
<th>Trends in Instrumentation and Control in the Pulp &amp; Paper Industry Panel</th>
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<tr>
<td>Tuesday Session 3 (3:30 pm-5:00 pm)</td>
<td>Session Moderator: Richard E. Britton – (Retired) International Paper; Mobile, AL</td>
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<td>Panelists: David W. Peters – Sigma Associates; Fairhope, AL</td>
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<td>Bob Barber – (Retired) International Paper; Cantonment, FL</td>
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<td>Ben Blanchette – Honeywell Process Solutions; Atlanta, GA</td>
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<td>Davis McAlpine – Hargrove Engineers &amp; Constructor; Mobile, AL</td>
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<td>Larry E. Wells – CCSA LLC; Atlanta, GA</td>
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<tr>
<th>Wireless Track</th>
<th>Utilize All Of The Data From Wireless And Smart Instrumentation</th>
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<td>Wednesday Session 1 (10:00 am - 11:30 am)</td>
<td>Session Moderator: Michael Jarreau; The JAC Group; Mobile, AL</td>
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<tr>
<td></td>
<td>AUDIO  POWERPOINT  PAPER  Being Smart with Smart Instruments - Ian Verhappen</td>
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<th>Industrial Wireless Applications</th>
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<td>Wednesday Session 2 (1:30 pm - 3:00 pm)</td>
<td>Session Moderator: Brad S. Carlberg, P.E.; Invensys; Lake Forest, CA</td>
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<tr>
<td></td>
<td>AUDIO  POWERPOINT  PAPER  Applying Wireless to Ethernet Pipeline Automation Systems - Jim Ralston</td>
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### Wireless Track

**Wednesday Session 3**
(3:30 pm - 5:00 pm)

**New Technologies for Wireless Applications**

*Session Moderator: James (Lyn) Givens; Fluid Flow; Mobile, AL*

- **POWERPOINT**  **PAPER**  Energy Budgets of Thermal Harvesting for Powering Wireless Sensors - Burkhard Habbe
- **POWERPOINT**  **PAPER**  The Reliability of Wireless Mesh Networks in Industrial Environments - Brian Cunningham
- **POWERPOINT**  **PAPER**  Ethernet I/O - Jim McConahay

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**Wireless Track**

**Thursday Session 1**
(10:00 am-11:30 am)

**Wireless Applications in Robotics, NC Machines, and predictive Maintenance**

*Session Moderator: Vincent LoPresti; Director - Process & Energy; PM Services, LLC; Mobile, AL*

- **POWERPOINT**  **PAPER**  Application of the next-generation emergency stop system utilizing functional safety wireless technology to outdoor life-supporting robots - Kazuya Okada
- **POWERPOINT**  **PAPER**  Wireless enables predictive maintenance for rotating assets - Jim Haza
- **POWERPOINT**  **PAPER**  Why Lord Kelvin Would Love MTConnect - Dave Edstrom

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**Wireless Track**

**Thursday Session 2**
(1:30 pm-3:00 pm)

"Ask The Wireless Experts" Panel

*Session Moderator: Brad S. Carlberg, P.E.; Invensys; Lake Forest, CA*

- **PAPER**  **POWERPOINT**  Panelists:
  - Dr. Penny Chen Yokogawa; Palo Alto, CA
  - Brad Lazenby – N-Tron Inc; Mobile, AL
  - Wayne Manges – Oak Ridge National Laboratory
  - Jim McConahay – Moore Industries; North Hills, CA
  - David McKay – Wingtip LLC; Kennewick, WA
  - Eric Rotvold – Emerson Process Management; Twin Cities, MN
  - Steven Toteda – VP & GM - Wireless at Cooper Industries Ltd.; San Francisco Bay Area , CA
  - Ian Verhappen – Director at Industrial Automation Networks Inc.: Edmonton, AB

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**Wireless Track**

**Thursday Session 3**
(3:30 pm-5:00 pm)

**Learn How The Oil & Gas Companies In Saudi Arabia And Northern Alberta Are Using Wireless**

*Session Moderator: Ric McNaughton; Maverick Technologies; Mobile, AL*

- **PAPER**  **POWERPOINT**  Aramco’s environmental monitoring data center - Paul Richards
- **PAPER**  **POWERPOINT**  Server Virtualization Services for Oil & Gas Applications: a User Prospective - Hassan Al Yousef
- **PAPER**  **POWERPOINT**  Wireless Application in Oil Sands Projects - James Wang
**WELCOME TO THE 3 ISA PULP & PAPER INDUSTRY DIVISION MEMBERS WHO HAVE RENEWED THEIR MEMBERSHIP SINCE MAY 2012**

Terry Grimaldi  
Thomas P. Barnett  
Jim I. Strausz, CCST

**HERE’S A REMINDER TO THE 34 ISA PULP & PAPER INDUSTRY DIVISION MEMBERS WHO NEED TO RENEW THEIR MEMBERSHIP**

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<td>Randall Anderson</td>
<td>Carlos A. Maguina</td>
<td>Prabu Govinda Perumal</td>
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<td>John L. Arnold</td>
<td>Camilo De Jesus Merino Melgar</td>
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<td>Paul Burnett</td>
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<td>Marcio Vieira De Camargo</td>
<td>Mike Muglia</td>
<td>Harjot Singh Randhawa</td>
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<td>Scott Childress</td>
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<td>Randal R. Claus, CCST</td>
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<td>Lakshmi Govindarajan</td>
<td>Ms. Mary Ann O'Connor</td>
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<td>Ezhil Raja Lakshmanan</td>
<td>Bruno Luis Pereira Oliveira</td>
<td>Akbar Talebi, PEe</td>
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<td>Adriano Roberto Ferreira Lopes</td>
<td>Jay T. Pearson</td>
<td>Adam Thomas</td>
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<td>Michael A. Maddox</td>
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**DON’T FORGET TO RENEW!**
International Paper commissions renewed Franklin mill

International Paper’s Franklin mill, reopened as a fluff-pulp operation, was commissioned in a ceremony Friday, Aug. 17, 2012. The pulp is used in baby diapers, feminine hygiene products and medical wipes. (Stacy Parker | The Virginian-Pilot)
By Stacy Parker The Virginian-Pilot August 17, 2012 ISLE OF WIGHT

It’s back, officially. International Paper’s Franklin mill was humming Friday with state and community leaders on site for a commissioning ceremony. Gov. Bob McDonnell, U.S. Rep. J. Randy Forbes and John Faraci, International Paper’s chairman and chief executive officer, addressed more than 200 people. Many of the guests were former paper mill workers who were rehired for the fluff pulp operation.

“I want to salute you,” Gov. McDonnell said. “You were the driving force ... so many people were hungry to get back to work.”

Allison Magness, the Franklin mill manager, also gave a nod to the workforce.

“It’s not often in life that you get a second chance. I’m so happy to be here today to celebrate that with you.”

The mill on Union Camp Drive began manufacturing fluff pulp at the end of June. The pulp is used in baby diapers, adult incontinence products, feminine hygiene products and medical wipes.

“We’re in the ramp-up stage now,” Margot Harding, product performance manager said. “We’re doing very well in terms of our start-up curve,” she said.

Harding said the mill is producing about 800 tons of fluff pulp each day, and is pursuing overseas exports where the demand is great.

The repurposing of the mill was International Paper’s top priority for 2012, Magness said.

When the mill closed nearly two years ago, more than 1,000 workers lost their jobs. The mill had been operating in the town for more than a century, dating back to its roots as a sawmill and lumbering operation.

In May 2011, the Memphis, Tenn.-based company said it would invest $83 million and hire about 200 workers to reconfigure part of the mill to produce fluff pulp.

It lived up to its word.

Today, steam rises from the smokestacks, the odor associated with paper production is back and the loblolly pines are steadily rolling into the plant on trucks.

“We knew this mill and this town was capable of a comeback,” CEO Faraci said.

He expects the mill will generate $250 million in annual revenue once it’s operating at full capacity.

A new company will join the mill soon.

ST Tissue LLC of Maryland will open a recycling plant by early October. It will invest $60 million for its operation to convert waste paper into napkins and towels. The project will create 85 jobs.

Isle of Wight County received a $200,000 grant from the Governor’s Opportunity Fund for the ST Tissue project.

Stacy Parker, 757-222-5558, stacy.parker@pilotonline.com
WHO’S DOIN’ ANYTHING?: (CONTINUED)

International Paper plans $30 million wastewater upgrade at Bogalusa mill in Louisiana, to be most efficient within company [From the web]

POPLARVILLE, LA, Aug. 17, 2012 (Local News) - Two executives from International Paper Co.'s Bogalusa, La., paper mill told supervisors on Monday that the company is five months into planning to refurbish the plant's waste water treatment facility, which will, when finished, be the most efficient and state-of-the-art waste water treatment facilities inside the company. The new treatment plant at the Bogalusa mill will cost IP an estimated $30 million dollars, the officials said.

Said Dr. Mike Steltenkamp, mill environmental, health and safety manager: "To say it will be one of the best in company is saying a lot because IP has plants all over the world - in Asia, Europe, and North and South America."

Steltenkamp said when IP bought the plant from Temple-Inland in February, the company was handed a plan, but IP officials wanted to revise it and submit a better plan to state officials.

Verso required to continue operating hydroelectric dam as Minnesota paper mill closes [From the web]

SARTELL, MN, Aug. 13, 2012 (Local News) - Just because Verso Paper Corp. won't be cranking out any more product at its Sartell mill doesn't mean activity there ends.

Rep. Michele Bachmann last week raised the possibility of a federal agency operating the Mississippi River hydroelectric dam at the site. But at least for now, Verso will continue to operate it under a 40-year contract with the Federal Energy Regulatory Commission.

The 46-foot-high, 388-foot-long dam, initially constructed between 1905 and 1907, was licensed to St. Regis Corp., a forerunner of Verso, on March 13, 1985. The FERC contract stipulates the license holder to operate the dam for 40 years unless a petition is submitted and approved to relinquish control. Barring any changes, Verso would be responsible for operating the dam until March 1, 2025.

The largest ever Northwest energy efficiency project

Executives from Weyerhaeuser, Nippon Paper Industries, Cowlitz County Public Utility District, and the Bonneville Power Administration (BPA), gathered at the North Pacific Paper Corporation (NORPAC) facility to celebrate the largest industrial energy efficiency project in BPA history and one of the largest energy efficiency projects in the United States to date.

When complete, the project is expected to save 100,000,000 kilowatt-hours per year. The energy savings from the completed project will save enough energy to serve approximately 8,000 Northwest homes. The first phase of the project was completed in June 2011 and the second and final phase is expected to be completed in the first quarter of 2013.

The project, referred to as a "Chip Pre-Treatment Inter-stage Screen Project," adds two new components to the NORPAC facility. The first change to the mill is the addition of the chip pre-treatment equipment. This equipment treats wood chips with steam and chemicals prior to refining the chips into pulp, resulting in reduced pulp bleaching and brightening costs. The second feature of the project is the inter-stage screening. Prior to the new screening process, wood chips were ground through two stages of refining. These refining machines are driven by numerous electric motors that require thousands of connected horsepower, which makes the refining process very energy intensive. The inter-stage screening process now allows paper-ready fibers (wood fibers that do not require additional refining), to bypass the second stage of refining, which results in significant electrical energy savings.

"Energy efficiency is the first-choice, least-cost alternative for meeting increasing demand for electricity in the Pacific Northwest," says BPA Administrator Steve Wright. "This project serves to meet our twin goals of promoting a healthy economy and a healthy environment in the Northwest."

NORPAC purchases power for its industrial operation through Cowlitz County PUD. Working through Cowlitz, BPA will fund
installation of screening equipment between refiners at the paper mill. The new processes will reduce electricity and chemicals used in the refining process, reducing the environmental impact.

BPA will fund about $21 million and Cowlitz County PUD will contribute up to an additional $3.9 million towards the project. The money contributed by both BPA and Cowlitz comes from their respective conservation funds, which provide financial incentives to their customers for the development and installation of electrical energy savings projects. NORPAC is funding the remaining $35 million of the $60 million project.

"This project is a win-win," said Dan Fulton, president and chief executive officer for Weyerhaeuser. "NORPAC's energy-efficiency project will allow this mill to remain competitive in an increasingly challenging global economic market by significantly reducing the mill's energy costs and decreasing its environmental impact through reduction of energy consumption and chemical use onsite. We are thankful BPA and Cowlitz PUD have partnered successfully with us to make this remarkable energy-efficiency project a reality."

In addition to significant energy and chemical use savings, the project created a surprise benefit. It allows NORPAC to produce a 92-bright ground wood sheet. This new product allows NORPAC to continue to diversify and expand the mill's product portfolio. Marketing for the new product, Norbrite 92, started in June of this year.

"Local workers came up with a creative and innovative idea, researched it, engineered it and got it approved-and local workers helped build it," said Cowlitz General Manager Brian Skeahan. "All of this demonstrates that the people of Cowlitz County make this a good place to do business. This project helps secure NORPAC's place as a cornerstone of our local economy."

ABOUT NORTH PACIFIC PAPER CORPORATION (NORPAC)
NORPAC is a joint venture between Weyerhaeuser Company and Nippon Paper Industries. The facility began operations in 1979 in Longview, Washington. NORPAC produces newsprint and high brightness publication papers. The facility operates three machines that manufacture more than 750,000 tons annually and is the largest newsprint and uncoated groundwood printing papers facility in North America.

ABOUT WEYERHAEUSER
Weyerhaeuser Company, one of the world’s largest forest products companies, began operations in 1900. They grow and harvest trees, build homes and make a range of forest products essential to everyday lives. They also manage timberland on a sustainable basis in compliance with internationally recognized forestry standards. At the end of 2011, the company employed approximately 12,800 employees in 11 countries, had customers worldwide, and generated $6.2 billion in sales from continuing operations in 2011. Weyerhaeuser stock trades on the New York Stock exchange under the symbol WY. Learn more at www.weyerhaeuser.com.

ABOUT BONNEVILLE POWER ADMINISTRATION
BPA, celebrating its 75th anniversary in 2012, is a nonprofit federal agency that markets renewable hydropower from federal Columbia River dams, operates three-quarters of high-voltage transmission lines in the Northwest, and funds one of the largest wildlife protection and restoration programs in the world. BPA and its partners have also saved enough electricity through energy efficiency projects to power four large American cities. For more information, contact them at 503-230-5131 or visit www.bpa.gov.

ABOUT COWLITZ COUNTY PUBLIC UTILITY DISTRICT
Cowlitz PUD serves 48,500 electric customers in Cowlitz County, WA, and is the second largest PUD in the state in terms of annual power sales. In addition to purchasing power from BPA, Cowlitz owns the 70-megawatt Swift No. 2 Hydroelectric Project on the North Fork of the Lewis River (WA) and has partnered with other Washington and Oregon utilities to develop the 98.9-megawatt Harvest Wind and 205-megawatt White Creek Wind projects in the Columbia River gorge.

For more information, please contact: Anthony Chavez (Weyerhaeuser), (253) 924-7148; Doug Johnson (BPA), 503-230-5840; or Brent Arnold, (Cowlitz PUD), 360-577-7502.
Well, it’s about a month until the ISA Automation Week 2012 conference at the Orange County Convention Center in Orlando, Florida. Go to the website and check out the technical program at Automation Week Technical Program Overview.pdf
FILTRATE BALANCE ON O2 DELIG UNIT VIA A MULTIVARIABLE LQG CONTROLLER

SAUL MTAKULA, P.ENG., M. E. - INTERCON PULP

PRESENTED AT THE PACWEST CONFERENCE 2012
"SUSTAINABILITY THROUGH PEOPLE & TECHNOLOGY"
FRIDAY, JUNE 1
AT THE FAIRMONT JASPER PARK LODGE, ALBERTA, CANADA
Filtrate Balance on O2 Delig Unit via a Multivariable LQG Controller

By Saul Mtakula, P.Eng., M. E.
Intercon Pulp
Introduction

► Washing is a vital component in cost control in pulp making.
► Must be done without causing filtrate inventory imbalances.
► Bad control has potential environmental consequences and leads to the unnecessary loss of material.
► We discuss multivariable linear quadratic gaussian (LQG) control of inventory.
► Implementation has been highly successful with operator acceptance and uptime higher than 90%.
► Level variability has been reduced by 16% and overflow has been virtually eliminated.

Summer 2012
Intercon O2 Delig Balance

Summer 2012
Intercon O2 Delig Features

- Two presses and associated pressate tanks and a Pre-O2 washer and associated filtrate chest.
- Most flow and level measurements available.
- Large volume tanks in comparison with flows e.g. #2 press tank is 323,263 litres for max flow of 60 litres/sec.
- Size of tanks informed decision to have controllers without integral action.

Summer 2012
Multivariable Model Determination

► Assume flows to have first order dynamics i.e to have gain, dead time and first order time constant.
► Assume levels are pure integrators with first order inflows and outflows mediating.
► Derive multivariable level model of the form.

\[
\begin{bmatrix}
L_1 \\
L_2 \\
L_3
\end{bmatrix} =
\begin{bmatrix}
\frac{K_p_1}{s(1+sTC)} & -\frac{K_p_1}{s(1+sTC)} & 0 \\
0 & \frac{K_p_2}{s(1+sTC)} & -\frac{K_p_2}{s(1+sTC)} \\
0 & 0 & \frac{K_p_3}{s(1+sTC)}
\end{bmatrix}
\begin{bmatrix}
F_1 \\
F_2 \\
F_3
\end{bmatrix}
\]
Determination of Model Parameters

- Gains $K_1$, $K_2$, $K_3$ obtained through simple arithmetic using tank dimensions.
- Time constant $TC$ user designed ‘reasonable’ value through lambda tuning.
- Model ignores the unmeasured inflows and outflows.
- Model shows coupling between the various levels and flows.
- No disturbances were explicitly modeled.
- Model can be summarized in so called state space format:

$$\dot{x} = Ax + Bu$$

$$y = Cx$$

Summer 2012
Linear Quadratic Regulator

► A form of controller based on optimization or minimization of an objective function

$$J = \lim_{T \to \infty} \int_{0}^{T} (x^T Q x + u^T R u) dt$$

► Assumes availability of the state.
► Controller synthesis is based on balancing Q and R.
► Good gain margin, phase margin and performance.
► State usually not available.

Summer 2012
Linear Quadratic Gaussian

- A state estimator/observer may be designed to allow an estimate of the state to be used for control purposes.
- One particular form of the observer is the Gaussian, based on assumptions of white noise disturbances and measurements on the process.
- Modified state space with white noise disturbance \( w \) and measurement noise \( v \).

\[
\begin{align*}
\dot{x} &= Ax + Bu + w \\
y &= Cx + v
\end{align*}
\]

- Covariance matrices \( W \) and \( V \), together with \( Q \) and \( R \) used to synthesize controller.
- Controller robustness degraded but may be recovered.

Summer 2012
Constraint and Bias Handling

- The control problem has constraints, most importantly minimum flows and maximum flows.
- The potential for integral windup exists when at the constraints for long periods.
- LQR/LQG controllers by default do not have integral action and usually suffer systematic biases from target.
- Took decision not to add integral action to the multivariable controller, obviating the need for anti-windup measures.
- Calculated offsets to deal with systematic biases by inspection and then sending biased errors to the controller.
- Implemented split ranging and position control during long constrained periods.

Summer 2012
Controller Development and Simulation

► Starting point was to choose initial Q,R,W,V and then simulate resulting controller in Scilab/Matlab.
► Initial choices were Q,R,W and V identity matrices of appropriate size.
► Initial controller simulated indicated that control action was particularly aggressive.
► Proceeded to then fix Q and W and modify R and V by multiplying them by factors 10 and then simulating the resulting controller.
► Settled for a few final controller candidates for actual implementation after simulation.

Summer 2012
Initial Controller

Summer 2012
Implementation in DCS

► Controller is generated in Scilab and is continuous time domain controller.

► Scilab tools used to generate discrete controller of form

\[ \dot{x}_k = A_k x_k + B_k u_k \]
\[ y_k = C_k x_k \]

► DCS that supports matrix math allows implementation of controls-true for Foxboro.

► Controller in DCS is subjected to step inputs and output is tested against Scilab step inputs to controller to ensure accuracy and build confidence.

Summer 2012
Controller Comparisons

Old (Sept 18-20, 2009)  New (May 5-7, 2011)

Old Controller Controlled Variables

Old Controller Controller Outputs

Multivariable Controlled Variables

Multivariable Controller Outputs

Summer 2012
Summary of Results

► Project demonstrated the viability of true multivariable controller in process industry
► Tools freely available (Scilab/Octave) that aid the number crunching required
► Simulation allows the designer to choose appropriate weighting factors for the right controller
► Implementation in DCS boils down to crunching of matrix math on control processor
► Controller has been successful and has been accepted by operators with uptime higher than 90%

Summer 2012
Questions, Comments

► Thank you!

Summer 2012
Filtrate Balance on O2 Delig Unit via a Multivariable LQG Controller

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ABSTRACT

In this paper we discuss the control of the Filtrate Balance on an O2 Delig unit using a multivariable Linear Quadratic Gaussian (LQG) controller. At heart the control problem was to manage pulp washing on three different units, the Pre-O2 washer, #1 Press and #2 Press while balancing filtrate inventories by maintaining levels in the associated filtrate tanks. The motivation for this was to correct existing Filtrate Balance programs, scattered throughout the Foxboro DCS system, consisting of a number of PID controllers and ad hoc calculations to manage the inventories and washing. The legacy system required frequent manual intervention by operators with overflows common and potential for a serious environmental incident. We demonstrate an analytic derivation of the approximate process models using tank volumes and flows, the generation and simulation of the LQG controller using Scilab, the implementation of the discretized state space controller directly in the Foxboro DCS, and the ‘tuning’ of the controller for satisfactory performance. We also discuss abnormal situation management and constraint handling, including the incorporation of bypass valves into the control scheme. The major results were, absent a disturbance a reduction in the level variability by 69%, and during disturbances the controls automatically ride out excursions without any overflow and requiring no operator intervention.

INTRODUCTION

The washing of stock before delignification is an important element of the production of pulp, with effective washing contributing to the reduction of overall production costs by leading to the reduction of bleaching chemicals.

Washing of necessity also involves the management of inventories of filtrate that are stored in large tanks. Figure 1 shows the general arrangement of the O2 Delig washing at Intercon. In the arrangement we have two presses, Press #2 and Press #1 followed by the Pre O2 Washer. Stock flows countercurrent to the wash flows as is typical in washing processes. Filtrate for washing passes through three large volume filtrate tanks, which essentially form a multivariable control system by virtue of the fact that what happens in an individual tank impacts the other two tanks as well. Ideally washing would proceed with the maximum possible flows to achieve the greatest possible washing, but the filtrate tanks impose a constraint in that those tanks should never overflow. Furthermore after passing through the O2 Delig washing stage, filtrate goes to the brown stock washing stage where washing would continue. The operators in the brownstock section independently set filtrate flow rates based on their own requirements. If they suddenly turned down the inflow into the brownstock washing system, the potential to upset the balance and overflow the pre O2 filtrate chest are high. The controls that were previously used to manage the filtrate balance, to prevent overflows or running tanks empty were based on basic standalone PID loops, with some additional logic to change level setpoints for upsets management.

![Figure 1: O2 Delig Filtrate Balance](image)

These controls turned out not to be so effective at carrying the function for which they were intended. Indeed on many occasions the pre O2 filtrate chest level would rise dangerously high. At this point the operators had to intervene manually, frequently by sending some of the filtrate to effluent. When these high level episodes occurred, production did not stop and the washing necessitated minimum flows to be maintained. It was in view of the controller deficiencies that we undertook to change the controls. A variety of approaches for improving the controls could have been taken, but we felt a multivariable controller would be the best approach, as the controller would be simultaneously ‘aware’ of what was happening with all three tanks at the same time and take the most effective control actions. It was not clear whether the approach we took would work, or what would happen when constraints were active especially with regards to windup and so the approach was to begin with idealized models, proceed through controller generation and testing via simulation. There are of course several multivariable controllers possible including MPC, H Infinity or LQG. The commercial MPC software at our site is not effective with integrating processes so was not considered but would have been the most effective at constraint handling since MPC controls make an explicit account of constraints in problem formulation. We started off with an LQG solution and once it appeared to be viable did not consider other approaches.

MODEL DERIVATION

For the purposes of analysis the control problem was assumed to be a multivariable level control problem. The levels were designated as follows, Pre O2 filtrate tank level L1, inflow into pre O2 filtrate, F1, Press # 1 level, L2, total inflow into Press #1, F2, Press #2 level L3 and inflow into Press #2, F3. We know that tuned flow loops are equivalent to first order processes with equivalent first order time constants which we designate TC1, TC2 and TC3 respectively to align with subscripts as defined above. If we designate the Laplace variable as s, then a first
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order time constant process with unity gain has the following transfer function for the \#2 Press

$$TF_2 = \frac{1}{1 + sTC_1} \quad (1)$$

There would be similar equations for the transfer functions $TF_1$ and $TF_3$ for the inflows into \#1 Press and the pre O2 filtrate chest. The unity gain assumption makes sense in that we can incorporate the actual flow gain into some composite gain for the level. A generic integrating process has the following transfer function

$$L = K_p/s \quad (2)$$

Where $L$ is the level and $K_p$ is an integrating gain and $s$ is the Laplace variable. Combining the ideas from equation (1) and (2) we can derive the following relation for the level $L_1$ with respect to the three inflows we alluded to.

$$L_1 = F_1 K_p/s(1+sTC_1) - F_2 K_p/s(1+sTC_2) + 0. F_3 \quad (3)$$

Equation (3) reflects the fact that for level $L_1$, $F_1$ is an inflow and $F_2$ is an outflow.

The same procedure can be repeated for level $L_2$ and $L_3$ to result in the following equations.

$$L_2 = 0. F_1 + F_2 K_p/s(1+sTC_2) - F_3 K_p/s(1+sTC_3) \quad (4)$$

$$L_3 = 0. F_1 + 0. F_2 + F_3 K_p/s(1+sTC_3) \quad (5)$$

Equation (5) is dissimilar to (3) to (4) in that there is no term that represents outflow because that flow is controlled by persons on a different control panel; we would later incorporate that information into the controller as feedforward information.

At this point we note that since we have the ability to make the flow closed loop first order time constants $TC_1$, $TC_2$ and $TC_3$ essentially identical as long as we choose reasonable value. One such method is the lambda tuning method; a suitable closed loop time constant would be the largest of the three lambdas for the three loops (which is strongly influenced by the longest dead time). We designate that common lambda $TC$.

Equations (3) to (5) may then be combined into the following transfer function matrix form. See [3] for matrices.

$$\begin{bmatrix}
L_1 \\
L_2 \\
L_3
\end{bmatrix} = 
\begin{bmatrix}
\frac{K_p}{s(1+sTC)} & -\frac{K_p}{s(1+sTC)} & 0 \\
0 & -\frac{K_p}{s(1+sTC)} & \frac{K_p}{s(1+sTC)} \\
0 & 0 & \frac{K_p}{s(1+sTC)}
\end{bmatrix} 
\begin{bmatrix}
F_1 \\
F_2 \\
F_3
\end{bmatrix} \quad (6)$$

The constants $Kp_1$, $Kp_2$ and $Kp_3$ may be obtained from simple arithmetic from knowledge of maximum flows and dimensions of the filtrate/pressate tanks.

It is easy using tools in Scilab to then go from the representation in (6) to one of the format in (7).

$$x = Ax + Bu \quad (7)$$

$$y = Cx$$

where $A$ is state matrix, $B$ is the input matrix, $C$ is the output matrix (in this case the flows) whereas the vector $x$ represents the system state which is tied to the output vector $y$ and combinations of the outputs and their derivatives.

We now note some of the operational constraints that apply to the balance.

- Total flows to either of the presses must never go below 24 litres per second (lps) and may go only as high as 60 lps. The pre O2 filtrate flow minimum is 50 lps while the maximum flow is 110 lps. These minima and maxima are manufacturer specified to prevent damage to equipment either through excessively low or high flows. Clearly operating at these constraints may be destabilizing because when maintained for long periods they do not match in and outflows.

- The tank volumes are respectively for \# 2 Press, \#1 Press and the pre O2 chest 294,768 litres, 323,263 litres and 725,316 litres.

LINEAR QUADRATIC REGULATOR

We briefly now discuss the linear quadratic regulator (LQR) as a control solution, and refer the reader to reference [1], [2] and [4] for a more complete discussion of this type of controller.

Linear quadratic controllers emerged out of research in the 60s around the question of optimal control for aeronautics. The basic idea was to synthesize a controller from the maximization of an objective function $J$ defined as follows.

$$J = \lim_{T \to \infty} \int_0^T (x^T Q x + u^T R u) dt \quad (8)$$

In equation (8) the objective function can be loosely considered to be some energy metric; the designer can then choose different values of $Q$ and $R$ as tuning factors which varies the energy distribution between the states and the inputs. A large value of $Q$ relative to $R$ would mean more energy in the inputs i.e. allows for large inputs and aggressive control actions whereas the converse would mean less aggressive control action.

The controller that results from the solving (8) is of the form

$$u = -Kx \quad (9)$$

where $K$ is the state gain. The controller that results has very good properties, with large phase margins and up to infinite gain margin if one considered a single input single output controller. The controller (9) may be synthesized if one has access to the state vector, which is not usually the case in the process industry.

LINEAR QUADRATIC GAUSSIAN

Absent the state vector one may use an observer to estimate the state, then proceed to use the estimated state vector as if it were the real state for controller generation. One such observer is a
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Kalman filter which when combined with the linear quadratic regulator results in the linear quadratic gaussian (LQG).

Equation (7) is modified to the form in equation (10) for analysis

\[ x = Ax + Bu + w \quad (10) \]
\[ y = Cx + v \]

In equation (10), \( w \) represents stochastic white noise and \( v \) stochastic measurement noise. The covariance matrices for the system noise, \( w \) and measurement noise, \( v \), respectively \( W \) and \( V \) are used as additional tuning factors in the solution of the LQG problem. In effect the observer problem is to solve for another objective function similar to that in equation (8) except \( V \) and \( W \) replace \( R \) and \( Q \), and the system for which the optimization is done has matrices system \( A^T \), \( C^T \), \( B^T \) rather than \( A,B \) and \( C \). The reader is referred to [1] and [2] and [4] for more details.

The observer solution is combined with the usual LQR controller solution to come up with a combined output feedback controller.

The resulting LQG controller is in fact a dynamic system with its own system matrices \( A_k \), \( B_k \) and \( C_k \) with its input vector being the error vector of the original system and it’s output being the input or control vector to the original system.

The LQG controller turns out not to have the same robustness properties as the LQR controller, typically with robustness severely degraded. There are formal techniques that try to recover those robustness properties, indeed loop transfer recovery techniques but we elected not to pursue those in the work carried out. The approach taken was to generate the controllers, simulate the results and analyze for performance and robustness. Different controllers could be quickly generated by varying \( Q,R,W \) and \( V \), with the resulting controllers simulated easily in Scilab/Xcos (or Matlab/Simulink).

INTEGRAL ACTION

By default controllers synthesized via LQR/LQG methods do not have integral action. The controller that results usually has systematic deviations from the setpoints. There exist techniques for calculating systematic biases for those controllers so that they achieve setpoints.

The usual way to introduce integral actions into the controllers is to augment the system dynamics in (7) with integral action, then synthesize a controller for the augmented system, with the final step being to transform the synthesized controller into a form suitable for the original system dynamics. Once integral action is implemented one has to deal with integral windup, which for multivariable controllers is not a trivial problem. In the case of the system at hand, depending on what is happening in the brownstock washer area, the system may have to sit constrained for long periods with minimum flows which tend to upset the balance, almost guaranteeing the need for anti-windup measures.

We made the decision to omit the integral action because it was felt the system had sufficient inherent integral action and also because the sheer volumes under consideration versus the flows meant that strict adherence to the required setpoints was not as important as keeping the system from veering off balance. Taking that decision meant there was no need to implement anti-windup measures, and that the controller could be implemented via just a series of matrix multiplications in the Foxboro DCS.

CONTROLLER ANALYSIS

As previously noted the equations in equation (6) were input into Scilab, with the resulting system matrices \( A, B \) and \( C \) of equation (7) extracted using Scilab tools. Initial weighting matrices \( Q,R,W \) and \( V \) were then chosen and an initial controller synthesized. The initial choices for \( Q,R,W \) and \( V \) were identity matrices of appropriate dimension. The initial controller was then simulated. Figure 2 shows the performance of the initial controller. The results indicate that one is able to get to setpoint of 70 from initial values of 0 within about 700 seconds which is a remarkable result for tanks with dimensions of up to 725000 litres. The fatal flaw with that conclusion as shown in figure 3 is that the flows could be as high as 2700 litres per second which is not achievable in practice as the largest flow actually available is 110 litres per second. Even if those flows were achievable they would be extreme and would have impact on upstream and downstream processes. Figure 2 also shows the systematic deviation from setpoint that we alluded to. While the example is certainly pathological, it is a good starting point for deciding which way one needs to go with regards to the relative magnitudes of \( Q, R, W \) and \( V \). An effective but crude way to proceed is to generate matrices \( Q=W=I \) where \( I \) is the identity matrix of appropriate dimension. Keeping \( Q \) and \( V \) constant one can go through iterations of the form \( R_1=V_1=I, R_2=V_2=10I, R_3=V_3=100I \) etc, generating controllers along the way and testing them via simulation for performance. Some sort of bisection becomes necessary when one has gone too far and needs to go back with the choices made. We proceeded this way till suitable values were felt to have been achieved.

![Figure 2: Initial Controller: Q,R,W,V identity matrices](image-url)
Filtrate Balance on O2 Delig Unit via a Multivariable LQG Controller

\[ x_k = A_k x_k + B_k u_k \]
\[ y_k = C_k x_k \]

where \( k \) is the subscript indicating the entity is for controller K.

We note that analysis and controller generation were carried out in the continuous time domain, yet we seek a controller to be implemented in the digital domain. Fortunately the tools in Scilab allow the discretization of the controller with one command to the form in equation (12).

\[ x_{kd}(i+1) = A_{kd} x_{kd}(i) + B_{kd} u_{kd}(i) \]
\[ y_{kd}(i+1) = C_{kd} x_{kd}(i+1) \]

where \( kd \) is the subscript for controller K discrete.

Implementation of the controller; as is clear from (12) involves code that will carry out the matrix multiplications listed. In [5] techniques for numerical manipulation of matrices are discussed. Those techniques were adapted and the discrete controller implemented in the distributed control system (DCS).

In order to see if there were numerical issues that could arise from the Foxboro implementation, equivalent step changes to the open loop controller were carried in Scilab and Foxboro and the dynamics responses compared; the Foxboro I/A controller was virtually identical to the Scilab controller which indicated it was numerically stable.

Having successfully synthesized the controller, we dealt with the issue of systematic bias from setpoint by sending to the controller biased errors rather than the true errors from setpoint.

The process by which the biases were determined was by simple inspection and was adequate for the purposes at hand; though as we have noted previously there are exact methods for calculating the requisite biases. Due to the ability to switch differently tuned controllers it was important that the set of biases be correct for the chosen controller since there was not one set of biases that worked for all the controller choice.

The control processors used, the Foxboro CP270 has the resources to carry out the computations even though the controller A matrix is 6 by 6 and executes every 1 second. In reality the controls could have executed less frequently because the tanks under consideration are very large in comparison to maximum in and out flows.

Once implemented the controllers were tested on the actual process. The first controller switched had good performance but had significantly moved variability from the levels to the flows. We then switched to a controller that struck the right balance between good level control and the right amount of activity in the flow controls.

Crude but adequate feedforward of the outflow from the pre-O2 filtrate chest was a question of biasing that flow to the chest inflow.

RESULTS

Figures 4 and 5 show the filtrate balance under the new multivariable controller and under the old control scheme over a period of some two days. In each of figures 4 and 5 the top trends are the levels and the bottom are the flows. Clearly the multivariable controller avoids the sustained periods over which the pre O2 filtrate level was over 100% and is usually able to ride out filtrate balance disturbances without reaching maximum level. The multivariable controller also is able to use more effectively the volume across the three tanks during disturbances. As is clear from the figure 4 there is no sign of windup, with the controller able to come out of the constrained condition gracefully. Figure 5 not only shows an inefficient use of tank volumes but also shows frequent manual intervention by the operator to deal with abnormality.

For the multivariable controller one of the most common abnormal situations when constrained was when the level Press #1 was rising and needed to be relieved into the pre O2 filtrate chest. There are two pathways into the chest, either the bypass valve or via the normal route into the chest. If level is go into the pre O2 chest anyway, the preference would be to do so while accomplishing some washing. To deal with this situation a position controller using a regular PID loop was configured to preferentially discharge high levels via the normal filtrate flow rather than via the bypass valve.

Another common situation was when the brown-stock wash rate had a dramatic increase in which case the maximum flow rate into the pre O2 chest was inadequate to maintain the level, while causing the Press #1 level to rise beyond the norm. This was dealt with by split ranging the flow into the pre O2 chest between the flow loop and through a characterized flow estimate of the bypass valve opening.
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in the pulp and paper industry. Controller uptime has been excellent at more than 90%.

REFERENCES

CONCLUSIONS

In this paper we have demonstrated the viability of a multivariable controller for a control problem in the O2 Delig filtrate system. Starting with pencil and paper derivation of the dynamics using tank volumes and flows, and without bump tests, multivariable LQG controllers were generated, simulated and validated within the Scilab environment. A state space form of the discretized controller was then implemented in the Foxboro I/A DCS with good results. Some split ranging and a position controller helped with abnormal situation management. The deliberate omission of integral action prevented windup concerns from ever arising. Simple biasing of errors that the multivariable controller saw, compensated sufficiently for systematic deviation from setpoints that characterizes LQG type controllers. There are tools available to the control engineer today for free (for example Scilab) which enable the implementation of fairly sophisticated controls for the problems

Figure 4: Multivariable Controller (May 5 – 7, 2012)

Figure 5: Original Controller (Sep 18-20 2009)
I asked our 2012 PUPID Scholarship recipient, Danielle Valdivia from Western Michigan University, to send me a quick note about her summer internship and she sent me this …

From: Danielle C Valdivia
Sent: Wednesday, July 18, 2012 9:05 AM
To: Brad Stephen Carlberg, P.E.
Subject: Write up

Mr. Carlberg,

I hope this helps you out a bit!

"I have spent the summer months working with a release liner company as an intern. I was required to become proficient in the company test methods in order to evaluate the silicone coated papers and films, tests such as release force, various paper property tests, FTIR, DSC, and atomic absorption. I was also expected to prepare coated sheets in the lab by formulating silicones, performing Mayer Rod draw-downs, curing the coated sheets sufficiently, and evaluating the coated specimens. I support the company coating plants with problem solving by testing production samples and by testing competitive samples to help design the best products available. As the summer nears an end, I will be running a project aimed to optimize certain properties of the company release liner and writing a report summarizing the results. I will be giving a presentation of the project and a summarization of all the projects I have worked on during my internship to the research and development leaders all before heading back to college for my senior year!"

If there is anything else I can do, just let me know.

Thanks!
Danielle Valdivia

Send your comments on this newsletter to me at brad.carlberg@bsc-engineering.com or post a message to the ISA PUPID Technical Discussion Forum List Serve & “get something started”!

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