EPRI / DOE - Instrumentation, Controls, and Automation
MEETING NOTES

EPRI's Instrumentation Controls, and Automation program (P68) in collaboration with the Department of Energy's (DOE) Office of Fossil Energy and the National Energy Technology Laboratory (NETL) hosted a meeting on Wednesday, June 6 and Thursday June 7 in Austin, Texas. The meeting was structured with the following agenda and attendees:

June 6

1:00 – 1:15	Welcome & Introductions	Neva Fox, *EPRI* Susan Maley, *DOE NETL*
1:15 – 1:45	DOE FE NETL - S&C Overview	Regis Conrad, *DOE Fossil Energy* Robert Romanosky, *DOE* NETL
1:45 – 2:00	EPRI I&C Program Overview	Neva Fox, *EPRI*
2:00 – 2:45	Roundtable	All
2:45 – 3:00	BREAK	
3:00 – 3:20	Overview Fiber Optic Sensing for Energy Applications	Anbo Wang , *Virginia Tech*
3:20 – 3:40	Tunable Diode Laser Sensors for Monitoring Combustion and Gasification Systems	Jay Jeffries, *Stanford University*
3:40 - 4:00	Novel Sensors and Control for Advanced Energy Systems	Mark Bryden, *Ames National Laboratory*
4:00 – 5:00	Facilitated Discussion and Closeout	All

June 7

8:00 – 8:10	Welcome	Neva Fox, *EPRI* Susan Maley, *DOE NETL*
8:10 – 8:30	Sensor and Control Techno-Economic Analysis for Existing Generating Units	Katrina Krulla, *DOE NETL*
8:30 – 8:50	Model Based Control for Power Systems	Aditya Kumar, *GE*
8:50 – 9:10	Model Based Control for Chemical Looping	Xinsheng Lou, *Alstom*
9:10 - 10:00	Facilitated Discussion	All
10:00 – 10:10	BREAK	
10:10 – 10:30	Cyber Security Solution – Demonstration of Integrity Software	Bill May, *PAS*
10:30 – 10:50	Wireless for Industrial Applications	*Oak Ridge National Laboratory*
10:50 – 11:40	Facilitated Discussion	All
11:40 – 12:00	Action Item and Closeout	All

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EPRI-DOE Instrumentation, Controls, and Automation Interest Group Meeting: Day 1 June 6, 2012 Session Notes

DOE FE NETL - S&C Overview

Regis Conrad – *Director, Division of Crosscutting Research*

- Program is focused on meeting industry needs; from HQ perspective, this means looking at safe, secure, economic, and science-based projects
- US energy challenges: competitive, secure, stewards of environment/environmental impacts (CO_2); water also a concern – water usage by power plants is second only to agriculture
- DOE Mission: to transform energy systems; educate next generation of engineers; secure nation; and management and operational excellence (Business Case)
- Cross-cutting Research: Fossil Energy Materials, sensors, controls & computational tools – a continuum of supporting science & crosscutting technology
- Office of Science Research ➔Fossil Energy Cross-cutting Research ➔Fossil Energy Core Programs
- Crosscut ting science, tools and technology development program supports breakthrough concepts, addresses gaps, and has commercial applications
- Power generation industry at critical juncture; competing demands; uncertainty of regulatory outcomes; reliable, low-cost energy
- FE's mission: increase efficiency/ mitigate CO_2 emissions in current plants; develop novel carbon capture ready power generation processes for the future
- Motivation is to develop new S&C technology: low cost; high benefit
- Key Gasification R&D areas – real need for S&C
- Combustion System: Oxy-combustion with Carbon Capture & Storage (CC&S); Advanced Process Integration; CO_2 Purification; Oxy-fueled Boiler; and Oxygen Plant; Oxy-combustion without CCS – cannot control plants
- Integrated S&C for Coal gasification - Advanced Control System (Multi-pollutant capture)
- Evolutionary versus Revolutionary – challenging conventional architecture to support advances in computational intelligence
- Distributed Sensor Coordination for Advanced Energy System: Smart Grid needs smart power plants; smart sensors➔efficient ties into smart grid
- Conclusions: challenges require innovations; times have changed; from 2009 to 2012 to 2013 – what is next? Cap-and-trade legislation? Cost of Oil? Impact of Gas? Impact of MATS? CCUS for EOR?
- Parting thoughts: HQ – energy security; revenues; trade (oil rate); CCS and climate change impact
- Important to engage outsiders – DOE values and wants **your** input, needs, and to engage in open discussions.

Discussion:
Q/C: CCUS power plan-utilize CO_2; what other options?
R/D: Challenges: expensive; on-going process; Utilization – knowledge not enough – 1% utilized-other option is storage. For example, NRAP project looking at storage/long-term liability
Q/C: Water was mentioned.
R/D: Water is a critical issue, however, Congress hasn't viewed water as critical issue, thus funding has been cut.
Q/C: Expand on wireless. Will it be integrated into wireless class of proprietary information or can be shared?
R/D: Lots of information/hurdles makes wireless not a viable issue; thermal, solar

Q/C: Security - active research on security addressing wireless gaps; communication; bringing wireless out of energy harvest; what can be taken and how should it be packaged? Lots of others are doing wireless work.

EPRI I&C Program Overview

Neva Fox – ***EPRI, Senior Project Manager, Instrumentation, Controls, & Automation***

What are problems now and in future?
Two pieces: 1) Technology and Demonstration
2) Technology Transfer; peer-to-peer, interactive, share experiences
Public Report Published on EPRI website, Report #1023502

Discussion:
Q/C: How to keep control system security – not owned by IT technology- How to develop control systems – nothing fundamentally being done.
R/D: How can some make comment that no one is doing something? Comment can be contested. Previous comments based-control loop ➔ control feed- not being done - can be contested.
Q/C: Smart transmission
R/C: build layer in new control network; will need to tie well together.

ROUNDTABLE DISCUSSION

All

Q/C: wireless technology ➔ smart transmitters – what we do for cyber security issues?
R/D: Fundamental develop control network
Turn into recommendation/comment/feedback- build in security at fundamental level; peer-to-peer community is there certain wireless networks – no wi-fi.
What is needed? More difference in field displayed – possibility to be mismanaged – but way sensors work – not very practical way performance to work; wireless data sources as data acquisition – data monitoring (yes); preventative analog (yes); controller shutdown (not a security issue)
We don't use wireless security information – 3rd level start to worry about sensitive information; for general purposes – not an issue; programmatic – wireless for mission-based.
EPRI & DOE provide guidelines for national security – plant security, environmental; nuclear wireless not for control system or using smart transmitters.
Q/C: Environmental sensors appropriate place for wireless sensors?
R/D: Monitoring but not control; done through fiber optics – wireless not considered – if controlled, will be fiber-optic; wireless used for performance monitoring.
Q/C: What do we need to improve?
R/D: 1) fidelity or wireless signal; goal: better than most think; 2) malicious jamming (military can do at any time) - higher than most think;
Plants along river, sub-harmonious for tug-boats – jammed- need more than one watt –60 Watt can be jammed.
Performance Assessment of wireless: 1) frequency hopping not an issue; 2) attack monitoring – can be directly attacked; almost all have guidance for secure deployment, but incorrectly deployed.
Q/C: How many people using asset management system that can be compared – malicious attack to original design and identify – attack system rather than configuration?
R/D: Parameters comparison of sensor to model and then further investigate rather than take immediate action.
Q/C: Instrument new protocols to be put in system – wireless or wired - concern if not in structure package in error check - improved redundancy check? Check to see if valid check used in industry? Not found in any of benign data but can be found in malicious.

If whole package, would whole package need to be produced? No (smart grid researcher) – let him inject malicious data bypass malicious data error protocol.

Encryption between sensors/can spoof engines – can send wrong information to computer and make engines act differently.

If someone wants to break-in and use data, security keys not an issue- data package is not secure; can make package if someone gets keys- keys can be pulled.

Q/C: What is one thing on your mind that is taking up time? Wireless devices concern or dominate through something else from I &C standpoint?

If diagnostic equipment would be preserved, is there connection of sensor to process – transmission isolated from process; jamming on wireless, but biggest sensor rates rather than cyber security

Joe Weiss: poor engineering on cyber security rather than cyber security.

Wrong problem diagnosing problem and problem made worse due to; lack of operation knowledge; lack of preventive maintenance; thinking is that this occurs and is unexpected; not only lack of preventive maintenance but things happen even with proper preventive maintenance in; natural disaster- alternative power and instrumentation for natural disaster; Security is the bottom line.

Instrument device – mismatch of cables, devices – implementation in same place- started as proprietary – different controls have to models – corporations change equipment with upgrades and as control person, retrofit system –whole system needs upgraded rather than instrument by instrument; problem may not be solvable –more standards are not an option – solved by corporation.

Open architecture.

Bus station- is there effort going on? Peer-to-peer indicates there are many – have to pick something; universal translator; whatever is picked, would be locked in.

some instruments have 2 or 3 options; looking for something that can talk – have to pick one and will be stuck with the one chosen for years.

*What are the issues that keep us awake? 1) cyber security, and 2) operator source

Around instrument and control identify big issues/key issues now.

Overview Fiber Optic Sensing for Energy Applications

Anbo Wang – Virginia Tech

Q/C: Intrinsic Fabry-Perot Sensors – inline process; IFPI Sensor Test on NETL Engine rig

Q/C: Sapphire preferred over silica on control side

R/D: Sapphire center is silica; no need for entire fiber to be sapphire; sapphire is expensive**.**

Q/C: Look at pressure

R/D: have used many pressures; silica-sapphire based pressure- up to 600^{o}C; long-time 700^{o}C;

Long-time other than sapphire-fuse silica fiber together; cannot use sapphire. Japan using sapphire rods – joined rods together by growing together; tried at Virginia Tech –made first hermetically sealed sapphire.

Tunable Diode Laser Sensors for Monitoring Combustion and Gasification Systems

Jay Jeffries – *Stanford*

Two parts: 1) T and H_2O sensing

2) CO, CO_2, CH_4, H_2O sensing monitor of systems that monitor of syngas heating value

Practical in harsh environments - air engine started ➔cool fired utility

IC engines – potential use in control of practical energy systems

Sensor strategies – two absorption measurement techniques:

Direct absorption (DA)

Wavelength Modulation Spectroscopy (WMS)

Vision and goals for TDL sensing in IGCC (please refer to presentation)

Novel Sensors and Control for Advanced Energy Systems

Mark Bryden – Ames National Laboratory

Information technology rapidly changing – won't recognize in near future
Stigmery- Agents interact with each other through the structure under construction (modifying their local environment) ; Most efforts have focused on sign-based stigmeric methods such as the ant colony optimization algorithm, network optimization, scheduling problems
Collective construction problem - piece is missing – that is piece being worked on- efforts not collaborated

FACILITATED DISCUSSION

All

Q/C: Multi-agent approach to control power plants started EPRI ➔Defense community/more intelligence
Hybrid graph – hyperlink – self-organizing, multi-agent that can share ➔structure being applied effort is there and started at EPRI
Q/C: Jay – H_2S and NH_3 – why assure balance was H?
R/D: Measure of H more problematic – can be measured, but not steady; H used in gas turbines – wants to remove H_2S and ammonia; capture direct H – there are projects, ways, technologies to remove H_2S and ammonia.
Q/C: Does calibration carry over or is special calibration needed?
R/D: Measure characteristics of laser when turned and modulated – no change
Q/C: NWMS: wave length and wave length mode
Q/C: What is vendor – what do you expect in order to move to next level? What is marketability? What is "enough" for DOE to take to commercialization? What would DOE like to have before licensing a product to go from science to technology?
End-user/utility – what level of maturity are you willing to take on market/ commercialization?
Are there demonstration products for DOE?
R/D: There are some that are user-friendly, but need to identify what utility can/will use; DOE doesn't want to fund "junk"; there is a roadmap for product development; if there are problems, product will stay in lab and will be moved out when problems are resolved.
Utilities have worked with commercial vendor who is near commercialization to work with universities on something that isn't even near commercialization; vendors work with universities ➔ vendors work with utilities
Trying to define requirements/specifications before start down road to development; allure in developing something that has not been done before
Q/C: Users: what do you need to run your business better? Define and then have those who want to develop something new are able to work to develop
R/D: Most utilities don't have resources – utilities are focused on next outage – but not what they do- sensors are wanted, but there is a disconnect – difficult to see outside the box
Trying to solve problem ➔ identify problem ➔ engineers solve problem
Scheme focuses on what is there and species not affected by what is there; measurement/ monitor in real time to make changes in process
User/utility: "does not want sensors (too expensive) and unless legislators demand sensor usage
Carbon capture and storage – future related to carbon piece; out of this project there will be better controls ➔ sell carbon
Sensors and controls are a necessary nuisance.
Gasifiers are necessary – sensors and controls are not necessary
How can DOE facilitate pilot facility of full-scale factory?
Challenge: What do plant look like in 10 – 20 years? Plants are not armed to make our jobs easier.
If brain PID, can you get there using PID controls?

EPRI-DOE Instrumentation, Controls, and Automation Interest Group Meeting: Day 2
June 7, 2012 Session Notes

Sensor and Control Techno-Economic Analysis for Existing Generating Units

Katrina Krulla – *DOE NETL*

Program planning analysis; look at content; conduct analyses for multiple programs at NETL to assess (economic):

- Market potential of technology
- Cost and performance
- Barriers to entry
- Benefits to society
- Evaluate sensors and controls
- Called into question the general rule of thumb that efficient plants cannot improve too much;
- Where role do sensors & controls play in market – clearly efficiency; process detailed in presentation
- Built Business Case tool – net present value analysis (NPV) for coal plant; obtained unit level data for Energy Velocity database – assumed pay back within two-year period

Conclusion:

- Advanced Sensors and Controls have the potential to be economically installed on existing coal power generation fleet.
- Availability is the key driver in determining the economics of refurbishment projects.
- Coal fired power plant CO_2 emissions could be reduced around 1% or 20 million metric tons per year from Advanced Sensors and Controls refurbishment.

Homework: What do we need to move Fossil Energy's Innovation index form -0.7 to +0.7?

DISCUSSION:

Q/C: Have you looked at natural gas?
R/D: Natural gas is built into model; used as a forward-looking model
Q/C: What are sensitivities?
R/D: The variables need to be set correctly.
Q/C: How did you estimate replacement – not a market clearing price?
R/D: Looked at market clearing price and revenue last; it is a high-level approach, and the numbers are not very specific numbers – may be averages.
Q/C: Workshops- fuel pass through clauses that would affect performance improvements
R/D: Who is in the money – who is not- did not factor into analysis.
Ties in well with survey; what obstacles prevent you from utilizing the latest I&C technologies to solve plant operating and maintenance problems?

Model Based Control for Power Systems

Aditya Kumar – *GE Global Research*

Why do we want advanced power controls? Efficiency, availability, flexibility
Gasification – complex plant – how do we operate entire plant in an efficient manner – bigger, more efficient?
Model-based controls reduce structural loads – increase capacity factor and annual energy output.
How can technology be brought to market faster? Model based controls are the way.
Model predictive control (MPC) – simple, flexible, robust-plants must be more predictable and effective

Focus on coal gasification section of plant. How can this be improved? Complement online sensors with model-based estimation – how do you prevent violation of boundaries? Are boundaries respected all the time? How do you increase performance? Faster startup faster load transient; optimized steady state performance; optimized performance.
Modeling for Advanced Controls: Need good transient models consistent with monitoring & control requirements.
Once model is built, how is it used? (real-time). Model will never be perfect; tests must be repeated; models must be fast enough for real-time.
What are challenges? How do we use models built to answer questions? What sensors will be used? How many sensors are needed? What are design requirements?

PRESENTATION DISCUSSION:
Q/C: Are you able to use models for all-fired boilers?
R/D: No work has been conducted.
Q/C: Where is GE – is there a special system for entire plant to be optimized?
R/C: The whole system is built from ground up; looking for gas and wind turbines; once proven, expand to commercialization (commercial product)
Q/C: Regarding development of intellectual property: how much is shared?
R/C: This is negotiated up from; the "how" is made public; details are not public – if information is needed, it is available
Q/C: Most of model – MPC – is there more leaking edge?
R/C: Old techniques – neural network genetics- very old technique (80s and 90s)- found not be realistic
Q/C: What are the motor techniques?
R/D: Gasifiers **-** simulated model –real time across the system model
Q/C: How are the physics-based model and ideas combined?
R/D: Done on a case-by-case basis
Heat transfer may not be well known; there is a basic correlation with parameters
The model by itself will never be accurate ➔ therefore, how do you do tradeoffs?
Q/C: IGCC uses a detailed physics-based model – design model or run gasification model? What package is being used?
R/D: Commercial package- not GE package.

Model Based Control for Chemical Looping

Xinsheng Lou - ***Alstom***

- Looking at whole project strategy
  Alstom: transport, high-speed, generation
- What is chemical looping (CL)?
- Oxyfired project is near-term
- Phase I (7/2007 – 9/2009) completed
- Future work:
  - Refine CL Prototype dynamic simulator
  - Install and test MPC design
  - Continue work on nonlinear MPC based on reduced order first principle model and empirical models

DISCUSSION:
Q/C: Assume saving. What is ration of saving in CL versus oxygen plant?
R/D: All potential CL technology options – technical solutions have advantages for DOE perspective if CL were common, CO2 –capture ready process has lowest pricing of electricity.
Advantage for Alstom: commercial perspective – meets the needs of different customers.
Q/C: Is MPC ROM used?
R/D: The first time, 3-4 dimensions were used; reduced dimensions of space; ROM can be linearized; the model can support wide range of models; future 5-10% of wide range – zero net load.

Q/C: How much funding is received from DOE? IS there cost-sharing?
R/D: Crosscutting Research contributes $1M; there is no cost-sharing; DOE interested in more novel, challenging projects that start small and if proven to be fruitful, additional funding will be added. Crosscutting Research is only funding controls; 3 megawatt pilot is running and was tested last week
Q/C: When will advanced controls be tested?
R/D: Currently validating advanced controls.
Q/C: Complexity of thought processes involving many loops; would networks be involved in the conceptual phase?
R/D: Networks and tools would need to be developed.

FACILITATED DISCUSSION

All

Survey results were narrowed down into potential projects.
Simple answer:
What is now the highest priority: **Tuning and Performance**
In the next 5 years: **Sensors**
10^{+} years: **Advanced Control Technology**
Barriers: **Cost**
Regulatory: **NERC**
Where to save costs and increase profit: **Diagnostics/Prognostics**

Tuning and Performance:

- Small acceptance by industry; over 50% has performance tool in some form- 10% in tuning
- End-user control guy; there is a lot of stuff already in plant; problem is that plant is not staffed to maintain technology; vendor installs stuff and leaves plant site; if something goes wrong, there is no one in the plant that understands the black box, so, box gets unplugged;
- Now, we want switch installed so it can be shut off; high probability it will work in the beginning, but model always needs tweaked and there is no one able to tweak at the plant
- Power industry is not staffed to maintain stuff- someone needs to maintain stuff; there is good stuff, but need thermal Ph.D. to maintain.
- Is there something embedded in system rather than added on?
- No. There are lots of embedded things, but algorithms are not used; have difficulty finding people who can tune PID controllers
- Staffing, level of knowledge, not-user friendly, staff is lean.
- Issue is not so much cost, but PID staff support; cost not as much a barrier, but staff support after installation; lose knowledge since not done very often- difficult to maintain knowledge at plant; costly for corporate engineers to re-train
- Great concept - how is it sustained? There are technologies, smaller companies, low cost and no advanced degree needed to run; smart design; haven’t done anything to market power generation
- Involved application in advanced controls getting better – find most success with continued involvement and basic ways to make APC work for long periods with low cost small maintenance agreement- it is possible – there are ways to make this work at a low cost.
- Hard to use, don’t work in plants; need things to just work; in addition to technology development, need to make it so it works; the human factor needs to be included – it is more difficult than we think; we have people who can do this – needs brought into discussions; for example, if a phone doesn’t work, there is a need to have people come in everyday and fix, or the phone could not be used.

- EPRI, what can be done? Infrequent tasks – EPRI is working on developing job cards; perhaps there is a need for "how to do job" cards. Train people to do job cards so employees would how to do infrequent tasks when need arises.
- Develop list of basic fundamentals and how to do tasks.
- PID becoming complicated.
- Control freedom in box.
- Trying to identify. One of the biggest issues in plants → not user-friendly. Job cards are great idea, but need to be user friendly.
- Goal from beginning is to be user friendly and anticipate end-user; GE had enough flexibility to make it work.
- Zolo: 1) reliability and 2) user interface – until actually on site, it is difficult to develop interface – enabled interface and got it to work
- MPC – main problem – have good models.
- MBC – getting model to work – funding, interfaced – one of the things up front is to get it right from the beginning – or else the whole project will fail.
- Robust control – could be barely blocked versus PID.
- Power generators – applications are available for turning loops.
- Final thoughts: user-friendly, standardized procedures.

Sensors: 5 years and out – new sensors

Q: Multi-variant systems – what sensors can we give to make it easier to tune?
R: issue: no shortage of sensors; the problem is whether the sensor survives environment, regulate/certified.

- Thermal couple: 1,000 – 1,100^{o} ; GE working on this at the system level.
- Non-intrusive flow sensors
- Nuclear power plant – sensors that can survive (situations like Japan) – under water, high radiation.
- Reliable heterogeneous two-way flow pulverized coal; precise measurements in coal power plant.
- Non-invasive and non-intrusive system → survive harsh environments - trying to prove survivability in harsh conditions.
- Power plants – online coal sensors – difficult to know efficiency without knowing coal composition of coal going in; is valuable or too hard to use – efficiency if coal fluctuates 5 -10%; does coal composition make a difference?
- Yes, important to control coal composition, especially dispatch controls; real time BTU analyzer is good stuff.

Cyber Security Solution – Demonstration of Integrity Software

Bill May – *PAS, Inc.*

Some challenges are not limited to the U.S.
CIP Inventory – sum of parts
Challenges and Solutions: Asset Inventory; change control configuration management; ports, services, & programs; patch inventory and management

Wireless for Industrial Applications

Stephen Smith - *Oak Ridge National Laboratory*

Trying to build wireless sensor networks that support and enable ubiquitous sensory advanced wireless sensors identified as critical research need.
"Engineered" versus "Can you hear me now?"
RF channels
Wireless landscape is extremely complex.
ISA 100.11 published by DOE industry standard for communication
Focusing on harsh environments for protocols – military /industry – wireless seen more in plants.

Discussion:
Q/C: Movement ➔ commercial sensors ➔ poses problems for end-users; Should we wait for movement?
R/D: In my opinion, worry about co-existence with other systems; interferon is a big issue; put sensors in band not utilized; practical issues won't be prevented; 915 more benign environments for integrity presentation; bands 245 and 915 are parallel and will not mesh; think of bands and their popularity.
Don't view this as hardship.
Q/C: Gallium nitrate powerchip – broad band
R/D: May be battery or line powered.
R/D: Probably cannot use wireless – can be done in some applications, but not broadly.
R/D: Energy harvesting with 700^o part of program.
Q/C: 700^o battery?
R/D: Yes, there are high temperature batteries, but packaging is an issue; a few years down the road, there will be a need to know what is needed so the path forward can be determined.
Q/C: Technical issues to work out: need pin – many aspects in industry pushing limits; process and materials are there but pricey. Gallium nitrate sensors, electronics, harsh environments – even discussing diamonds.

FACILITATED DISCUSSION

All

Q/C: Where do you see Diagnostics/ Prognostics;   Profit and Profitability?
R/D: D&P have great value –turn into some action that can be performed; not there yet
Q/C: What is next step? What is the key next thing?
R/D: We have lots of devices but to plant - different generators to generators differ plant makes it difficult
Q: Controls and diagnostics define problem and how much left to control and how much left to operators.
Prognostics- do you have tools to make decisions; life versus performance
Model Key thing: control same theory, same design, difficult application; sub-topic
Virtual sensing, process model- continues monitoring, came out of real time/virtual Prognostics- power markets (primary); 15 minute window   predict load depending on user, time, scan   determine cycle   goes to predictive/future reference - to generate production Q/**C:** IGCC- Alstom. Is anything being done with ultrasupercritical?
R/C: Most of DOE work is done on Materials
R/C: VATech working with Alstom – sensor for temperature for next generation power.
Q/C: Need something to measure damage to translate to control materials
R/D: VATech is working on a new project with the goal to develop a sensor for materials, sensing, monitoring, multiple sensor systems for up to 1,000^o C.
Q/C: Procedures – plant or process- how do you translate to control logic? Should be able to make system with start of one common framework that computer and human understand or have computer in a language that humane and cabbies understand.

Q: Sensor: requirements future ticks

1. Reliability ,especially harsh environments – reliable operation
2. Drift free – over many degrees;, would have to re-calibrate sensors-want to eliminate
3. Self-diagnostic_ if sensor fails, operator will know
4. Cost as low as possible
5. Advanced sensors increase work load <u>now</u> – hope and assurance that workers work load decreases and not increases; reduce work load.
6. Robust harsh environments for long periods of time; will this provide the opportunity to get cheap snow and if not ripped out; don't want to go around testing sensors.

WHITE BOARD NOTES

Tuning and Performance

- Low market acceptance for tuning / high market acceptance for performance
- Black boxes get unplugged
- After sale, service and maintenance, onsite staff not knowledgeable on tuning and control of software
- Low availability of staff
- Need 'user-friendly' tools
- Currently available tools need PhD to use – not long-term practical
- Keep and maintaining knowledge for this area at a plant level
- Looking for other ways to maintain systems including use of APC
- Job cards to further develop in this area ➔ need cheat sheets for infrequent tasks
- Need training for technicians and plant engineers
- Still needed but with improvements in 'user friendliness of devices, tuning, controllers, APC, etc

Sensors

- Placement
- Survivability in a harsh environment / abnormal conditions / high rad levels / underwater
- Need to survive Fukushima type of event
- Certified for certain uses
- Analyze sensor combo to infer things that can't be measured ➔ state estimation / virtual sensing
- Global measurements with point and feature extraction

Specific Sensor Needs

- **Non-Intrusive** Steam Quality Measurement
- Replace TCs with 1000 – 1100 F steam line temp measurement – 3 yrs for calibration, 10 yr life
- Non-Intrusive Flow Sensors (fuel, flow and steam)
- Coal Flow analyzer – real time BTU ➔ efficiency and performance
- Material damage sensors – 1000 F ➔ can identify corrosion/cracking on steam side and high energy piping

Diagnostics and Prognostics

- Need to answer the question – how long can we run between outages?
- How to integrate with controls
- How much can be accommodated with controls vice shutting down and doing maintenance
- Informed decisions via use of systematic tools
- Models to enable analysis and predictive capability
- Hybrid knowledge and model approach
- Virtual Sensing
- Basis exists for prognostics ➔ external to grab data for prediction

Other Open Comments

- Translate procedures into control logic ➔ Narrative turns into logic ➔ Logic and Procedures always the same
- Sensors – Improve reliability / drift free / self diagnostics / lower cost / lower work load