IPRO 303

Information Design for Plant Management to Predict Equipment Failure

FINAL REPORT

TABLE OF CONTENTS

ADDENDA LIST: (in approximate order of importance)

Addendum 1 **Requirements Document** A stand alone document of 2 pages.
Design Ideas Summary This covers design ideas that resulted from generating the Requirments Document and do not fit with that document. A stand alone document of 2 pages.

Addendum 2 **User Interface Design Content Document** This is the description of the Final User Interface Design. A stand alone document of 12 pages.

Addendum 3 A simple cut and paste of notes from those who visited the power plants. This document serves to capture in raw form, the knowledge gained from these visits. This also includes some screen shots of Bailey Controls UI. A stand alone document of 10 pages.

Addendum 4 A simple cut and paste, unedited record of the original 3 UI Designs generated for discussion with SmartSignal on Wednesday, March 12, 2008. A stand alone document of 7 pages.

Addendum 5 A Budget Accounting for IPRO 303, Spring Term 2008.

Addendum 6 A nearly final accounting of time expended on IPRO 303, Spring Term 2008.

ABSTRACT

IPRO 303
Information Design for Plant Management to Predict Equipment Failure

Objective

The goal of IPRO 303 was to design a User Interface (UI) for monitoring and predicting equipment failures in coal fired power plants. The desired UI would enable plant personnel to understand the faults, prioritize the disposition of the faults and reduce the need for plant personnel to have many years of experience to be able to utilize the UI in managing the power plant.

Basic Organization and Tasks

IPRO 303 delegated responsibilities to sub-teams to design the UI and satisfy the IPRO deliverables. The initial sub-teams included: High Level Design Team, Communication Team Fault Analysis Team, Project Plan Writing Team, Midterm Report Writing Team, and Ethics Report Writing Team. As the IPRO progressed the following additional sub-teams were created to complete the IPRO: Design Content Team, Screen Shots Team, Requirements Document Team, Final Report Writing Team, and Oral Presentation/Poster/Slide Team.

Accomplishments

The IPRO 303 team met its goal of designing a UI with the desired features. It created computer screen shots to demonstrate the performance of a number of its features. It also created a Requirements Document which will provide SmartSignal, our sponsor, a means for continuing the IPRO and to further develop the UI.

Critical Barriers and Obstacles

Our sponsor, SmartSignal, wanted the team to take an open ended approach and develop concepts without being constrained by preconceptions. This, when coupled with the team's limited knowledge of power plants, made ramp up of the IPRO slow and difficult. Also, the team found the work of the previous IPROs did not contribute significantly to the success of this IPRO. Scheduling power plant visits was slow and difficult, which delayed getting important information.

Conclusion

The IPRO designed a UI interface for monitoring and predicting equipment failures in coal fired power plants. This UI design meets the design objectives. The team also created a Requirements Document and Design Description that will facilitate a subsequent IPRO or corporate development of the UI. The work product of this IPRO can be used to improve the management of power plants. The team's entire work product is stored in iKnow.

Next Steps

SmartSignal should review and consider our Final Report, Design Content Document, Requirements Document, and screen shots. Based upon their review, SmartSignal may narrow the scope of research or further develop some aspects of the IPRO's design. SmartSignal should also consider the competitive positions of both OSIsoft Inc's PI system and Bailey Control's power plant control software.

Faculty & Advisors: Edmund Feldy PE

Team Leader: Ray Simons

Team Members: Jacob Dodds, Samad Erogbogbo, Rachel Fleming, Haruko Fujimoto, Nirav Hazariwala, Jihyung Kim, Sangwook Lee, Arthur McAnally

IPRO 303

Information Design for Plant Management to Predict Equipment Failure

FINAL REPORT

Instructor: Edmund C. Feldy PE
Sponsors: SmartSignal
IPRO Team: Jacob Dodds, Samad Erogbogbo, Rachel Fleming, Haruko Fujimoto, Nirav Hazariwala, Jihyung Kim, Sangwook Lee, Arthur McAnally, Ray Simons
Date: Monday,April 28, 2008

1 Introduction

The Spring semester of IPRO 303: Information Design for Plant Management to Predict Equipment Failure, is designing a User Interface [UI] for monitoring and predicting equipment failures in coal fired power plants. The two IPRO groups which preceded ours identified the key power plant personnel, their decision making procedures and daily activities.. Our user interface will be the product of considering the work of the previous IPROs, input from our sponsor, SmartSignal, new research, and the creativity and innovation of our team.

2 Background

A. **Sponsor Information:** SmartSignal is a corporation that provides applications to increase equipment performance by means of predictive analysis. SmartSignal's solution analyzes information gathered from every piece of equipment of power plants, monitors behavior of the plant as a whole, and identifies the level of contingencies. SmartSignal's clients include a number of major power plants nationwide and worldwide. The company is located in Lisle, Illinois. SmartSignal's product is applied in many industries but this project focuses on Coal Fired Electric Power Plants.

B. **Current User Problems:** An improved User Interface is needed for monitoring and controlling operating conditions in coal fired power plants. The current system causes information overload because the monitoring screen displays an unmanageable number of warnings at one time There are many false alarms and operators are not able to effectively sort and parse errors. There is a need for a User Interface that can present relevant information and early warning reports directly to the plant workers involved in the problems predicted or occurred.

C. **Technology Involved:** Designing skills are necessary in order to create User Interfaces which efficiently display information. Programming knowledge enables us to provide visual representations of our design.

D. **Other Attempts to Solve the Problem:** SmartSignal personnel are also working on alternative User Interface solutions. We learned that there exist many current different User Interfaces in power plants.

E. **Ethical Issues:** SmartSignal operates in a competitive market and any classified or sensitive information or documents obtained from the SmartSignal company will be kept confidential and will not be disclosed to anyone outside the project team. The team will not disclose the identity of our sponsor to power company personnel

F. **Business Cost:** There is a trend of young inexperienced employees gradually replacing older knowledgeable staff in power plants; the loss associated with this is irretrievable. The UI aims to bridge this gap by making information more available and enabling users to personalize the information they access using the UI.

G. **Sponsor Direction:** SmartSignal specifically requested that the team work the problem with limited exposure to SmartSignal's product and wanted the team to approach the problem with an unbiased perspective.

H. **Current Team Objectives Vs. Previous IPRO 303 team objectives:** The current team's objective was to design a UI. The previous semesters objective was to gather information relating to the normal activities of the plant personnel. This difference is further discussed in section 6, Obstacles.

3 Purpose

The purpose of this IPRO is to design and deliver a User Interface for use in coal fired power plants. The UI will utilize SmartSignal's predictive analysis software to provide and display in an efficient and clear manner for power plant personnel to:

- Predict or identify equipment faults
- Understand the predicted faults
- Prioritize the disposition of the predicted faults or highlight urgent or important faults
- Reduce the need for plant personnel to have many years of experience or "institutional knowledge"

The ultimate goal of this project is to introduce an innovative approach to the user interface which SmartSignal can use for predicting equipment failures in coal fire power plants. To realize this, we set these objectives.

- Research and collect information relative to the User Interfaces [UI] from the first hand users of the software.
- Create the Requirements Document for the UI in light of the concerns expressed by SmartSignal and the results of research.
- Generate several possible UIs based upon the Requirements Document stated above.
- Select one of the Several UI for development of details and revise it based upon the input from SmartSignal.
- Add details and finalize the design of one UI.

4 Methodology

Project Methodology: The Team met with our sponsor SmartSignal, to further understand the task at hand. Our sponsor's representatives gave a presentation to the team. In their presentation they described how the software works through the modeling, analysis and recommendations for possible failure of a power plant component or equipment. Again, our sponsor requested the problem be addressed without any bias from actually seeing the software's current UI or a sample prediction. After the meeting and without the benefit of seeing the software an approach was gradually fashioned. The following are the tasks that were outlined by the team as a viable approach:

The following bullets indicate the problem solving process used in approximate order of activity.

- Gained a better understanding of how a power plant works as a system through a presentation by the previous IPRO instructor.
- Performed an Open Ended brainstorming to identify and define possible User Interfaces.
- Generated multiple User Interfaces that applied all the information gathered
- Presented the multiple UI's to our sponsor, SmartSignal, and collected feedback. Our sponsor encouraged us to compile the UI concepts into a single best version.
- Performed further research using available resources to gather more information on standard UI structures.
- Visited and observed two power plants not using SmartSignal software
- Interviewed plant members to understand the chain of decision-making that is or is not present in a power plant. An example of such a decision making chain could be: a plant staff that is responsible for a specific plant component, sees an alert (problem) and is responsible for alerting

someone else. The flow and storage of this information should be easily accessible for historical access.

- Gathered and analyzed the types of information used by plant personnel.
- Using the above information generated a User Interface Requirements Document to capture the knowledge gained.
- Developed the final User Interface based on the comments or suggestions from presentation to sponsor. Documented this design in a Design Content Document and by creating several examples of UI screen shots.
- Present final User Interface to sponsor. [Planned]
- Throughout the process, all the time we documented our effort within the various IPRO deliverables and other records stored in iGroups.

5 Assignments

Throughout the project term all teams were held accountable by the entire project team during regular project team meetings. Assignments were made and refined via brainstorming during class meetings and as needed.

Initial Assignments:

Initially. Sub-team members were assigned based on their technical skills, Major of study, familiarity with determined tasks. There were three (3) sub-teams formed: High-level design team, Communication team, and Fault analysis team. Each of the sub-teams had a leader to ensure that everything progressed in a timely manner. The team assigned officer responsibilities such as appointing Project Leader, Minute taker, and Master scheduler.

Initially the team created three sub-teams to achieve the overall objectives of the project. The three sub-teams are:, The High Level Design Team, The Communication Team, and The Fault Analysis Team.

The High Level Design Team, conducted research using available resources to gather information on UI structures. Based upon this research and the results from the other two teams, the high level design team developed three initial conceptual approaches for the design of a UI. Each of three team members was responsible for developing a conceptual approach. The three approaches were:

- The "Directionally Linked UI". This UI has also been described as a "Top Down" approach. The primary focus of this UI was to keep the computer screen simple by presenting a limited amount of information at any time while allowing the user to access more detailed information as needed.
- The "Search and Solve UI". This UI enabled the user to begin with a graphic or view of the power plant and point and click to examine any specific system, machine or part to investigate a specific incident.
- The "Full Disclosure UI" is similar to the " Search and Solve UI" but adds the feature of being able to designate error priority levels based upon a color coding system.

Team Make up: Arthur McAnally – Directional Link UI
Jihyung Kim – Full Disclosure UI
Haruko Fujimoto – Search and Solve UI

The Communication Team, was created to research information flow within the power plant, visit power plants and conduct, interviews with plant workers. It was to find links and hierarchies within the plant departments. The team was to make flow charts of information flow in the power plants. The team was to provide design concepts to the high level design team based on its interviews and research. In reality, the team generated a list of potential questions relating to the flow of information in a power plant. It also scheduled the visits to Midwest Generation's Waukegan and Crawford power plants. Most Project team members visited one of the plants and gathered information for the further development of UIs. The feedback of information from the plant visits to the High Level Design Team came not just from the Communication Team but from all Project Team members who visited the plants.

Team Leader: Rachel Fleming
Members: Sangwook Lee, Ray Simons

The Fault Analysis Team, was created to decide which pieces of data/information were to be in the reports sent to workers/shift supervisors/engineering specialists. It was to determine who needs what kinds of information under certain circumstances or accidents. The team defined the state/level of warning, alert, incident, and fault. The team also developed mechanisms that effectively deliver the reports to the appropriate people. The team generated a list of questions to ask power plant personnel to gain an understanding of what information is needed to enable them to effectively analyze faults. The Fault Analysis Team members visited the power plants and one team member, Nirav Hazariwala, was afforded an extended time interviewing unit operators in the control room of the Waukegan plant.

Team Leader: Jacob Dodds
Members: Samad Erogbogbo, Nirav Hazariwala

Subsequent UI Design Assignments:

After the three initial UI concepts were developed, the Project Team presented the concepts to our sponsor, SmartSignal, for their feedback. SmartSignal liked some features from each of the three concepts and encouraged the team to take the best of the three concepts and develop one final UI. The Project Team then determined that new sub-teams were needed to finish the design. The team created the following teams to complete the creation of the UI:

The Design Content Team, had the task of creating a specification for the content of the final UI. The team defined the make up of the UI and how it would function. It conveyed this specification to the Screen shots team. Because of time constraints this process was as much an evolution as it was a hand off.

Team Leader: Arthur McAnally
Members: Rachel Fleming, Jihyung Kim

The Screen Shots Team, was responsible for taking the specification from the Design Content Team and creating actual screen shots for the UI. Their approach was to develop a web based prototype of the UI. The prototype will be displayed during the IPRO Day poster session.

Team Leader: Jacob Dodds
Members: Haruko Fujimoto, Nirav Hazariwala

The Requirements Document Team, was responsible for creating a document which lists the design requirements the UI satisfies. This document will be valuable to SmartSignal for future development of subsequent UI's , to future IPROs on this project and provides and important historic record of our design criteria.

Team Leader: Nirav Hazariwala
Members: Sangwook Lee, Ray Simons

Additional Teams Created to Manage/Complete the IPRO

The project team, while developing the UI, concurrently realized that additional teams were needed to satisfy the IPRO requirements including the creation of all of the deliverables.

The Project Plan Writing Team, wrote and submitted the report defining our project.

Team Leader: Ray Simons
Members: Samad Erogbogbo, Haruko Fujimoto

The Midterm Report Writing Team, wrote and submitted the Midterm report documenting the progress of the team as of March 14, 2008.

Team Leader: Ray Simons

Members: Samad Erogbogbo, Arthur McAnally

The Ethics Report Writing Team, wrote Our Code of Ethics which guided our IPRO.

Team Leader: Jacob Dodds
Members: Rachel Fleming, Arthur McAnally

The Final Report Writing Team, wrote this report, the comprehensive record of the project, design history and result.

Team Leader: Ray Simons
Members: Samad Erogbogbo, Jihyung Kim, Arthur McAnally

The Oral Presentation Power Point/Poster/Brochure Team, was responsible for Creating the presentation Power Point slides, poster and brochure for our Project presentation.

Team Leader: Rachel Fleming
Members: Jacob Dodds, Haruko Fujimoto, Jihyung Kim

The Waukegan Power Plant Information Gathering Team, visited the power plant, interviewed plant personnel, gathered information, photographed the facility and existing UI screen shots.

Members: Professor Ed Feldy, Nirav Hazariwala, Jihyung Kim, Ray Simons

The Crawford Power Plant Information Gathering Team: visited the power plant, interviewed plant personnel, and gathered information. Photographs were not permitted in this facility.

Members: Professor Ed Feldy, Jacob Dodds, Arthur McAnally, Sangwook Lee, Haruko Fujimoto

The Final Presentation Primary Presenters: These members were given primary responsibility for making the IPRO Day presentation. All team members will participate.

Members: Arthur McAnally, Samad Erogbogbo, Ray Simons

Individual Responsibilities:

The project team also assigned Individual responsibilities to members to facilitate the management and organization of our IPRO.

Overall Team Leader: Ray Simons

Meeting Minutes: Rachel Fleming

Managing iGroups email organization: Jihyung Kim

Managing iGroups files organization: Arthur McAnally

Regarding Team Building:

Several members attended the IPRO Games to develop team building skills. However we concluded we would develop our teambuilding skills through the actual process of assigning and performing as a team and many sub-teams. All indications are that we were very successful with this approach. No significant teamwork problems have arisen. We still plan to complete the required peer evaluations.

Regarding Communication Activities and Effectiveness:

The team communicated regularly during its regular meeting twice each week. These meetings were used to maintain accountability, communicate progress and create and assign new sub-teams. Many sub-team meetings were held outside of class. Also email was a major means of communication. Our communications were very effective and no serious problems have occurred. The only communication conflicts that have occurred have been between members of different sub-teams. These were resolved during the regular class/team meetings with non sub team members contributing and the Faculty Advisor acting as moderator.

6 Obstacles

An initial obstacle was the lack of clear direction from SmartSignal. The team wanted SmartSignal to provide definition or attributes of a desirable UI. SmartSignal wanted the team to take a more open ended approach and develop concepts without being constrained by preconceptions. This obstacle was overcome when the team accepted this lack of definition and launched into brainstorming concepts.

The initial lack of team organization was an obstacle. Because the team had difficulty defining a direction in which to work, it had difficulty knowing how to organize as a team. Once the team decided to develop three design approaches it became obvious that our organization should be around our three teams.

Individual student schedules made meeting outside normal class times difficult to schedule. Many occurred late and often at odd hours. This scheduling problem also constrained the make up the teams. On occasion, schedules made it impossible to have individuals with the desired skill sets participate on certain teams.

We expected the information from the previous IPROs to be more useful than it proved to be. We viewed this as an obstacle. It necessitated our teams gathering information from power plant personnel which could have been gathered during the previous IPROs. We overcame this obstacle by doing the research and gathering the information during our two power plant visits.

Scheduling power plant visits was slow and difficult. Reaching appropriate personnel and scheduling power plant visits were obstacles. As mentioned above, we visited two coal fired power plants owned by Midwest Generation. The information gathered during our plant visits and the feedback from SmartSignal visit enabled the team to move forward and successfully complete this project.

7 Results

Initial view of the Project and Learning:

Because we were the third IPRO team working on the SmartSignal project we started by reviewing the previous IPRO documents and we invited the leader of last semester's team to visit our class to discuss his team's work. We did not find the work of the previous IPROs to be very helpful. After reviewing the project description and the previous work we decided we would define our task as "Making Recommendation(s) for Improvement of the (SmartSignal) Interface". We thought we needed to limit the scope of our assignment and not try to tackle an open ended, undefined, design project. We also knew we did not know much about power plants so we invited professor Chmielewski to make a presentation explaining how coal fire power plants work. Then we met with SmartSignal to learn about their product and what their expectations of the IPRO were. SmartSignal described their product and define factors they wanted us to consider. But SmartSignal wanted the team to do more than just propose improvements. They wanted us to develop a UI without considering their current UI. They wanted the team develop UI considering the following customer needs:

- Clear presentation of fault information and reduction of those errors which are either false, or not as urgent, as the software indicates.
- Context around core incident-general state of the plant and ambient conditions.
- History of fault development and progression
- Efficient communication mechanics
- Seamless flow between incident, notification, investigation, resolution-action

Once we accepted this approach we proceeded to develop teams and assignments.

Post SmartSignal Feedback:

After our initial meeting with SmartSignal the project team met to brainstorm our understanding of what the UI should be and do. We concluded that our UI should utilize already existing knowledge of coal-fired power plant equipment failure prediction and make the information manageable as well incorporate the following qualities:

- Easily accessible and understandable information
- Integrates all the decision-makers at the power plant
- Clear presentation of information or analysis of results

To develop our UI we defined the following actions we would take:

- Get a better understanding of how a power plant works as a system.
- Interview plant members to understand the chain of decision-making that is or is not present in a power plant.
  An example of such a decision making chain could be a plant staff that is responsible for a specific plant component sees an alert and is responsible for alerting someone else. The flow and storage of this information should be easy and accessible for historical worth.
- Analyze information received from the power plant staff interviews.
- Perform further research using available resources to gather more information on standard UI structures.
- Design multiple User Interfaces that applied all the information gathered from previous steps as well integrating the little knowledge of the pre-exiting UI.
- Present multiple UI's to our sponsor, SmartSignal, for feedback and to provide a progress report.
- Revise or Rebuild or Re-design the User Interface based on the comments or suggestions from presentation to sponsor.
- Presentation of new or revised User Interface to sponsor.
- Final UI

The 3 UI Concepts:

Utilizing the teams described previously in this report, three UI concepts were developed. The High Level Design Team, proposed three initial conceptual approaches for the design of a UI. They were:

- The "**Directionally Linked UI**". This UI has also been described as a "Top Down" approach. The primary focus of this UI is to keep the computer screen simple by presenting a limited amount of information at any time while allowing the user to access more detailed information as needed.
- The "**Search and Solve UI**". This UI enables the user to begin with a graphic or view of the power plant and point and click to examine any specific system, machine or part to investigate a specific incident.
- The "**Full Disclosure UI**" is similar to the "Search and Solve UI" but adds the feature of being able to designate error priority levels based upon a color coding system.

The team presented the three concepts to SmartSignal and requested their feedback. SmartSignal liked some features from each concept and requested that we combine the best of all three UIs and create one final UI. **Addendum 4**, provides a simple cut and paste, unedited record of the original 3 UI Designs generated for discussion with SmartSignal on Wednesday, March 12, 2008.

Plant Visit Knowledge Acquired:

The knowledge we gain during our plant visits was very valuable. During both visits we had the opportunity to witness the operation/function of a coal fired power plant. Plant personnel walked us through the actual process of generating electricity. At the Waukegan plant we were able to take many photographs of the plant and relevant screen shots. We learned how currently the plants are monitored and controlled. And what operators find lacking in the current system. We also learned in what format the operators are use to or prefer. We came to understand that a major problem with the current UI is the management of a large number of errors/faults/incidents which in fact may not need disposition but continue to appear as needing disposition. We also learned that actually 2 systems are being used in the plants one utilizing Bailey Control's[1] and the second, OSIsoft Inc.'s[2] PI system.

[1] http://www.abb.com/cawp/seitp161/f05b13130762f1f8c1256de4003c32c3.aspx
[2] http://www.osisoft.com/ http://www.osisoft.com/Products/PI%20System/

During the Crawford plant we confirmed many of our findings from Waukegan. We were unable to take photos or screen shots from this plant. More detailed information from our plant visits is attached in **Addendum 3** which is a simple cut and paste of email notes from those who visited the power plants**.** Also several more photos are available in iGroups. Below are a photo of the control room at the Waukegan plant and a picture of a screen being used today.

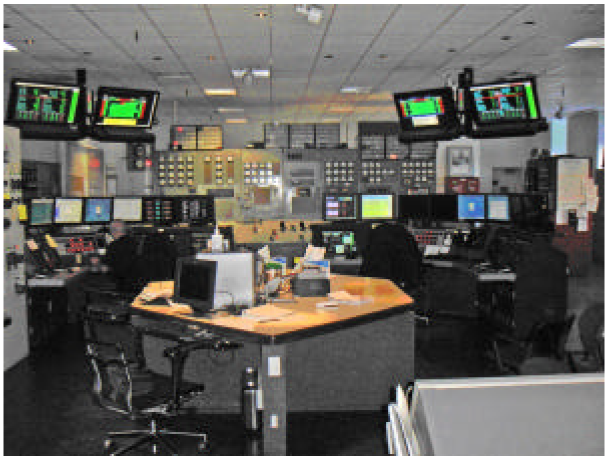


photo of Control Room (Waukegan Plant)

photo of Bailey Controls screen (Waukegan Plant)

Requirements Document Generated:

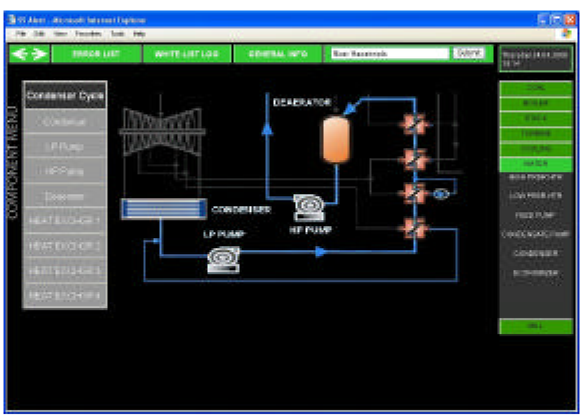
The team realized that a Requirements Document would help the team develop and capture its understanding of what features/specifications the desired UI would have. As our understanding grew we created the Requirements Document. It defines the required elements of the UI. We also believe this document has tremendous potential value to SmartSignal. The Requirements Document can be used by SmartSignal as a stepping off point for further product development or IPRO activity. If additional information regarding the Requirements Document is needed, it is attached to this report as **Addendum 1**.

Design Description Generated:

The team generated a UI design that meets much of the Requirements Document. The end-user, power plant personnel, and SmartSignal stated a need for the UI to enable personnel to recognize and disposition phantom or erroneous errors and reduce the reporting of phantom errors. The proposed UI does this. Below is a screenshot of the error screen that enables personnel to more effectively disposition errors. This includes white boarding which is the transfer of error messages to a separate screen as candidates for permanent deletion as phantom, recurring errors/messages.

Example of Error Screen sorted by Time. **(Further examples of screens are in Addendum 2)**

It was also required that the UI reduce or eliminate the steep learning curve of new employees and the UI structure had to be easy to navigate and understand. The access to various features had to be quick without cluttering the information. The pace of work at the power plants is such that the system and UI had to be quick and easy to use so its use would not adversely affect productivity. The UI design satisfies these requirements with easily accessed screens that clearly display conditions and historical data at the component level. Below are example screen shot showing this type of information.



Example of Component Screen

Example of Component Screen

These are just several examples of how the UI design satisfies the Requirements Document. For further information refer to the Design Content Document which is attached as **Addendum 2**.

Our Solutions:

- Clear presentation of fault information and reduction of errors which are either false or not as urgent as the software indicates.
  - The UI enables the operator to "White List" (permanently ignore) and or filter errors. This is achieved through personalized UIs (login/out).
- Context around core incident-general state of the plant and ambient conditions.
  - The UI separates the reporting of conditions and provides navigation through a particular aspect of the plant to evaluate an error.

- History of fault development and progression
  - The UI relies on SmartSignal historical error analysis and requires the user to log high level errors and allows logging any and all errors.
- Efficient communication mechanics
  - The function of the UI increases the efficiency of communication mechanics by the automatic distribution of critical information such as the white lists. Error logs reduce the need for one on one communication and reduce the steep learning curve experienced by newer employees.
- Seamless flow between incident, notification, investigation, and resolution-action
  - Linking errors to a particular employee responsible for solving the error allows quick resolution.

What Did We Learn:

We learned many things during this IPRO. We gained a basic understanding of the operation of coal fired power plants. We learned how plant operators monitor the plants, gather detected error information and respond to error conditions. We gained an understanding of what works well and what doesn't in the management of power plant error information. We learned how to take a very undefined project and turn it into a focused UI design project. The team learned how to function as a team through brainstorming, and sub-dividing to accomplish tasks. As a team we learned how to manage ourselves and our activities. We learned how to succeed as a team.

8 Conclusions and Completion Activities

Power plants have a real need for a UI with many of the features included in our UI. The team will meet with SmartSignal to make a final presentation of our UI to maximize their ability to use our work to further develop the UI and hopefully, eventually meet the market need for such a UI.

If and when a UI with the design features incorporated in our UI is brought to market, power plant management will be possible using personnel having less plant experience. Fault analysis will be easier and based upon more specific and detailed information.

Other completion activities include a final submission of expense reports, the creation of the CD and the uploading of all critical information onto iKnow.

A budget resolution status is attached as **Addendum 5**.

A final Table of Contents for the CD documenting this IPRO cannot be provided because not all final documents are loaded into iKnow at this writing: However the CD will contain *.pdf documents for the following:

IPRO 303 Abstract, Raymond Simons, Created on: April 25, 2008
This is the Abstract from IPRO 303: Information Design for Plant Management to Predict Equipment Failure.

IPRO 303 Team Minutes, Rachel Fleming, Created on: April 18, 2008
This is the Team Minutes from IPRO 303: Information Design for Plant Management to Predict Equipment Failure.

IPRO 303 Midterm Report, Raymond Simons, Created on: March 14, 2008
This is the Midterm Report from IPRO 303: Information Design for Plant Management to Predict Equipment Failure.

IPRO 303 Code of Ethics, Jacob Dodds, Created on: March 07, 2008
This is the Code of Ethics from IPRO 303: Information Design for Plant Management to Predict Equipment Failure.

IPRO 303 Final Presentation, Version 3 complete
Run though planned for April 30, planned iKnow load date April 30.

IPRO 303 Poster, Document complete
Being printed, planned iKnow load date April 30.

IPRO 303 Final Report, This document complete
Planned iKnow load date May 1.

A nearly final accounting of time recorded is attached as **Addendum 6**. This cannot be final because activities are scheduled for after completion of this Final Report.

9 Recommendations

SmartSignal should read and consider this report, our Requirements Document and Design Content Document. They should then use these documents to narrow the scope of the UI design project for future exploration and product development.

SmartSignal should focus on the Technical Specialists more than the Plant Operators.

SmartSignal should examine the market positions of Bailey Control and OSIsoft Inc. SmartSignal needs to detail how their product fits relative to these 2 company's products within the power plant industry.

10 References

1. Problem solving lecture and notes, provided by Professor Edmund C. Feldy PE, Illinois Institute of Technology.
2. Power Plant Presentation, by Professor Donald J. Chmielewski PhD, Illinois Institute of Technology.
3. IPRO 303 semesters 1 and 2, Final Reports and other documents on file on iKnow.
4. Product and Project presentation by Mr. David Farrell and Ms. Stacey Kacek of SmartSignal Corporation.
5. Sample error reports from Midwest Generation Corporation.

11 Acknowledgements .

Donald J. Chmielewski PhD, Assistant Professor of Chemical & Environmental Engineering, Illinois Institute of Technology, 127 Perlstein Hall, 10 W. 33rd Street, Chicago, Illinois, 60616, email: chmielewski@iit.edu. Professor Chmielewski provided the project team with a presentation explaining the basic make up and operation of coal fired power plants. He also advised the Design content team during the final stage of the UI development.

Mr. Gerald Delaney, Chemical Process Specialist, Midwest Generation,LLC, Fisk and Crawford Stations. Mr. Delaney hosted our teams visit to the Crawford plant. He provided the team with an informative tour of the power plant.

Mr. David Farrell, Product Manager, SmartSignal Corporation, Lisle, Illinois. Mr. Farrell, with Ms. Kacek, provided the IPRO team with an overview of SmartSignal's business and their objectives for the IPRO. Mr. Farrell also provided feedback relating to the 3 initial UI design concepts and direction for completing the final UI.

Ms. Stacey Kacek, Vice President of Product Development, SmartSignal Corporation, Lisle, Illinois. Ms. Kacek, with Mr. Farrell, provided the IPRO team with an overview of SmartSignal's business and their objectives for the IPRO. Ms. Kacek also provided feedback relating to the 3 initial UI design concepts and direction for completing the final UI

Mr. Scott Lehman, Lehman Electric Company, 630-942-1900. Mr. Lehman introduced the team to Mr. Michael Sedlak, facilitating our visit to Midwest Generation's Crawford plant.

Mr. Mark Nagel, Engineering Manager, Waukegan, Midwest Generation, 401 East Greenwood Avenue, Waukegan, Illinois, 60087, 847-599-2243, email: mnagel@mwgen.com.

Mr. Nagel provided a very thorough and informative tour of the Waukegan plant. He made control room personnel available to answer our many questions.

Mr. Michael Sedlak, Chief Electrical Engineer, Midwest Generation, 815-207-5872, 312-935-2472, Email: msedlack@mwgen.com . Mr. Sedlak arranged our visit to their Crawford power plant.

Karl Stolley PhD, Assistant Professor, Illinois Institute of Technology, the Humanities Department, 208 Siegal Hall, Chicago, Illinois, 60616 312-567-3151, email:kstolley@iit.edu. Professor Stolley attended SmartSignal's project presentation and provided guidance regarding the design of our UI.

IPRO 303

Information Design for Plant Management to Predict Equipment Failure

User Interface Requirements Document

Final Version

Instructor: Edmund C. Feldy PE
Sponsors: SmartSignal®
IPRO Team: Jacob Dodds, Samad Erogbogbo, Rachel Fleming, Haruko Fujimoto, Ray Simons, Nirav Hazariwala, Jihyung Kim, Sangwook Lee, Arthur McAnally
Authors: Nirav Hazariwala, Ray Simons, Sangwook Lee
Date: Monday, April 28, 2008s

Overall Goals for the User Interface:

The User Interface (UI) will utilize SmartSignal®'s predictive analysis software to provide an efficient and clear means for power plant personnel to:

- Predict or identify equipment faults
- Understand the predicted faults
- Prioritize the disposition of the predicted faults or highlight urgent or important faults
- Reduce the need for plant personnel to have many years of experience or "institutional knowledge"

The above overall goals reduce to a User Interface that has the following characteristics:

- Makes information manageable
- Integrates all decision-makers at the power plant
- Provides easily accessible and understandable information

Hierarchal Requirements List:

The following list documents things that we feel are needed in order to meet the above overall goals. Each is designated either with the letter (R) which means this is requirement for the UI or with a (D) which means this is desirable but not absolutely required.

01.0 Provide relevant information to the appropriate people with a need to know (R)

- 01.1 The UI should not have (extra) information the user does not need. (D)
- 01.2 The UI should look different for different users. (D)
    - 01.2.1 The UI splits up into different categories for different people/departments with links to each other. (D)
- 01.3 The UI must provide ways for users to dig deeper into the problems and learn more about the problems. (R)
    - 01.3.1 The UI is to provide a way to access historic data about the problem. (Knowledge Base) (R)
    - 01.3.2 The UI is to provide a way to augment historic data about the problem. (Knowledge Base) (R)
    - 01.3.3 The UI is to provide help to user in viewing & interpreting the history of similar faults. (Knowledge Base) (R)
    - 01.3.4 The UI is to provide a "white-listing" option to mark an error as not actually being an error. (R)
- 01.4 Provide an indication of the current status & severity of faults. (R)
- 01.5 Provide an overall indication of the context of any problem within the overall asset & plant status. (D)
    - 01.5.1 The UI is to provide critical information needed by all workers. (R)
    - 01.5.2 The UI is to provide a means to archive critical information. (R)

01.6 Provide for display of pictorial graphics, charts, graphs and numerical data tables. (R)

02.0 Be Easy-to-Use (D)

02.1 The UI will make use of right and left click access similar to web based systems for digging deeper into the problem. (R)

02.2 The UI will make use of left click access to pop-up windows for explanation and options. (D)

03.0 Allow for easy prioritization and maintenance planning (D)

03.1 The UI should provide for ready display of asset information such as: age of the asset, the next scheduled maintenance, and the time since the last maintenance. (D)

03.2 The UI should provide the user a record of how many times the same error occurred with the same issue on the same machine during some definable timeframe. (D)

04.0 Provide for Easy & Efficient communication mechanisms among plant staff (R)

04.1 Phone "Auto-dial" to appropriate equipment operator to alert of level 5 or above errors. (R)

04.2 Status report pops up when shift transfer is occurring (e.g. when a new operator logs into the system). (D)

04.3 Auto Emergency shutdown capability (D)

05.0 Provide for seamless flow between incident notification, investigation, and resolution action (R)

IPRO 303

Information Design for Plant Management to Predict Equipment Failure

Design Ideas Summary

Instructor: Edmund C. Feldy PE
Sponsors: SmartSignal
IPRO Team: Jacob Dodds, Samad Erogbogbo, Rachel Fleming, Haruko Fujimoto, Ray Simons, Nirav Hazariwala, Jihyung Kim, Sangwook Lee, Arthur McAnally
Author: Nirav Hazariwala, Ray Simons, Sangwook Lee
Date: Monday, April 28, 2008

Description

The requirements document states the things that the designed User Interface will do or offer. On the other hand, design specification expresses how those features will be implemented. This document lists the items that can assist either in stating the methodology of actual designing of the UI or the designing itself. These items are also supporting information for the requirements document as well, in the sense of describing it in more details. Suggested design ideas and areas to be considered are classified into three groups according to their characteristics. This document is to be reviewed by the Design Content Team so it may be incorporated into design specification.

Items to be implemented

- Appearance of the UI
  1. The UI might have a structure that uses one home screen as a base point from which to get anywhere.
  2. The design is function effectively whether implemented as primarily as "Black on White" screens similar to paper printing or as "White on Black" screens as is currently used in Power Plant control rooms.
  3. The design is function effectively when used on screens with native aspect ratios of 4:3 and 16:9.
  4. The UI has a menu bar as a navigation tool that contains references to sub-menu elements.
- Dealing with errors:
  1. Operator input required for all errors of level 4 or higher
  2. No flashing lights for error notification due to unmanageable number of errors appeared at a time
  3. The design is to make consistent use of different colors to classify and indicate priority of various errors codes.
- Functionalities:
  1. Users can get benefit from having a search function. The search scope in the search box, the content to be searched, and the manner how searched result is displayed are to be determined.
  2. A back button can help users navigate through the UI. Implementing more navigation buttons is definitely useful.
  3. The UI, as displayed on a monitor, does not take a framed or fixed size window. Instead it will be shown on a re-sizable and movable window.

4. It is helpful for users to contextualize the errors occurred if the UI generates pictorial graphics of data relevant to such errors.
5. A small window that notifies critical information needed by all workers can be shown in a scrolling manner at the bottom of the home screen.

Areas to be considered but are not required

1. When user see the error information on the error screen, user has to click on that error and its leads user to the error's particular piece of information such historical data, context information for person, current data, etc.
2. Different user like to see different screen as per user need and related to error.
3. UI should have a auto dial, email, message popup per each unit.
4. UI have a multiple screen environment so user can open more then one screen at a time and also work with multiple screen at a time mean UI is must have a user friendly environment.

IPRO 303

Information Design for Plant Management to Predict Equipment Failure

User Interface Design Content Document

Instructor: Edmund C. Feldy PE

Sponsors: SmartSignal

IPRO Team: Jacob Dodds, Samad Erogbogbo, Rachel Fleming, Haruko Fujimoto, Nirav Hazariwala, Jihyung Kim, Sangwook Lee, Arthur McAnally, Ray Simons

Design Content Team: Samad Erogbogbo, Rachel Fleming, Jihyung Kim, Arthur McAnally

Date: Friday, April 11, 2008

Introduction

The team's aim was to design a User Interface [UI] for monitoring and predicting equipment failures in coal fired power plants. The problem statements as determined by the team through briefings from our sponsor SmartSignal® as well as through further research are addressed by the UI design. There are four major problems identified by the team.

Firstly, the end-user, power plant personnel suggests that the current error reporting system occasionally produces phantom errors. Since the errors are determined by the system and the user has no input into the way the errors are determined, the team keyed-in on this as a reason for the number of unwanted errors and also the reason for too many errors.

Secondly, there is a steep learning curve that has to be overcome by employees with little or no power plant experience. The new employees have to learn on the job but the current tools are not sufficient for a relatively quick learning process.

Thirdly, the UI structure has to be easy to navigate and understand. The access to various features has to be quick without cluttering the information. The pace of work at the power plants is such that the system and UI have to be quick and easy so as not to slow down productivity.

Finally, Communication amongst the power plant personnel has to be facilitated by the UI. This is also related to the issue of the steep learning curve. Based on results from research into power plants, a design requirements document was developed to outline the requirements for a UI that would address the problem statements. The requirements document states requirements for a UI that addresses the problems but it also suggests innovative solutions for monitoring and predicting equipment failure in power plants. Some of the requirement document solutions have been incorporated into an actual UI design and are described in this document.

Error Screen

Figure 1: Error Screen (Time sorted), Figure 2: Error Screen (Sorted by Intensity)

The screen shot above shows the Error Screen. This screen displays all the errors in the plant as they occur determined by the error prediction system. The errors can be sorted by the user based on whatever best suits them. The error screen has various buttons that address the issues mentioned in the introduction. The errors can be sorted by any of the following: error priority level, time error occurred, date error occurred, asset name, state of asset, section of the plant, and by operator/personnel name

Delete: Any plant personnel can use this button to delete an error from the list after a resolution of the error or as they may see fit.

Login\Logout: This is used to help the system allow privileges as well as keep track of who did what on the system.

White-list: This button is used to stop an error from re-occurring. It can only be used by plant personnel who have pre-assigned privileges. The plant supervisor or any other personnel in the same capacity determines who has privileges to this feature. An error is white-listed if it has been determined that the error is a none-error; a none-error is an error that is either deemed not relevant or incorrect. After an error has been white-listed the system keeps count of who white-listed the error and the error description. After a pre-determined number of people with privileges have white-listed the same error, (about 50%, for example) the plant supervisor is notified and he can stop the errors form showing up on the errors screen using his master privilege.

Error List: This button is a navigation button. It is used to return to the error screen from anywhere in the system.

Add Error Log: This feature allows for an operator to share his reasoning or comments about an error. It links to a different screen. This is related to the issue of a steep learning curve for new plant employees; new employees can gain experience faster by having access to such information. This error log becomes an important component of the power plant historic knowledge base.

View Error Log: The error logs are stored for similar/same errors on an asset. The error log also has sorting capabilities. It can be sorted using the following: date of error, time of error, and operator that added the error. It links to a different screen.

Filter: The filter is a feature that allows a user to set the minimum and maximum priority level errors displayed on the error screen. The refresh button allows the filter action to be carried out.

Back\Forward Arrows: They are both navigation buttons that allow the user to go to a previous screen either in the forward or backward direction.

White-List Log: The white-list log button links to a different screen that allows the user if they are logged-in and if they have privileges to view their white-list history. The user can choose to reverse a white-list or view other errors white-listed by other people on the same asset. The screen is different for the plant supervisor so that he has a view of the entire white-list history as well as eradicated errors.

General Information: The general information button links to a screen that displays varied information about the entire plant operation. For example, the screen could contain the coal usage by the power plant over a given period of time.

Sectors: The sector buttons represent sections of the plant. The sectors are based on components that are in that section of the plant. It allows for easier navigation of the system. By clicking one of those components, the screen changes to the specific component and some related parts to it. More detailed explanation will be in the next screen shot.

Some of these buttons are global buttons, displayed on every screen, used for navigation.

The following are the global buttons: Login/logout, error list, sectors, general information, white-list log, and the back\forward arrows.

The buttons on this screen address the problems stated earlier. The Filter option, white-listing, and sort features tackle the issues with error reporting. The white-list log also helps with the communication amongst power plant workers; it keeps the engineers informed of their colleague's thoughts or actions without actually conversing with them. While the view error log and add error log help to reduce the steep learning curve that new employees have to overcome. The division of the plant into manageable sectors helps to improve navigation; this is a function of the research done on power plants.

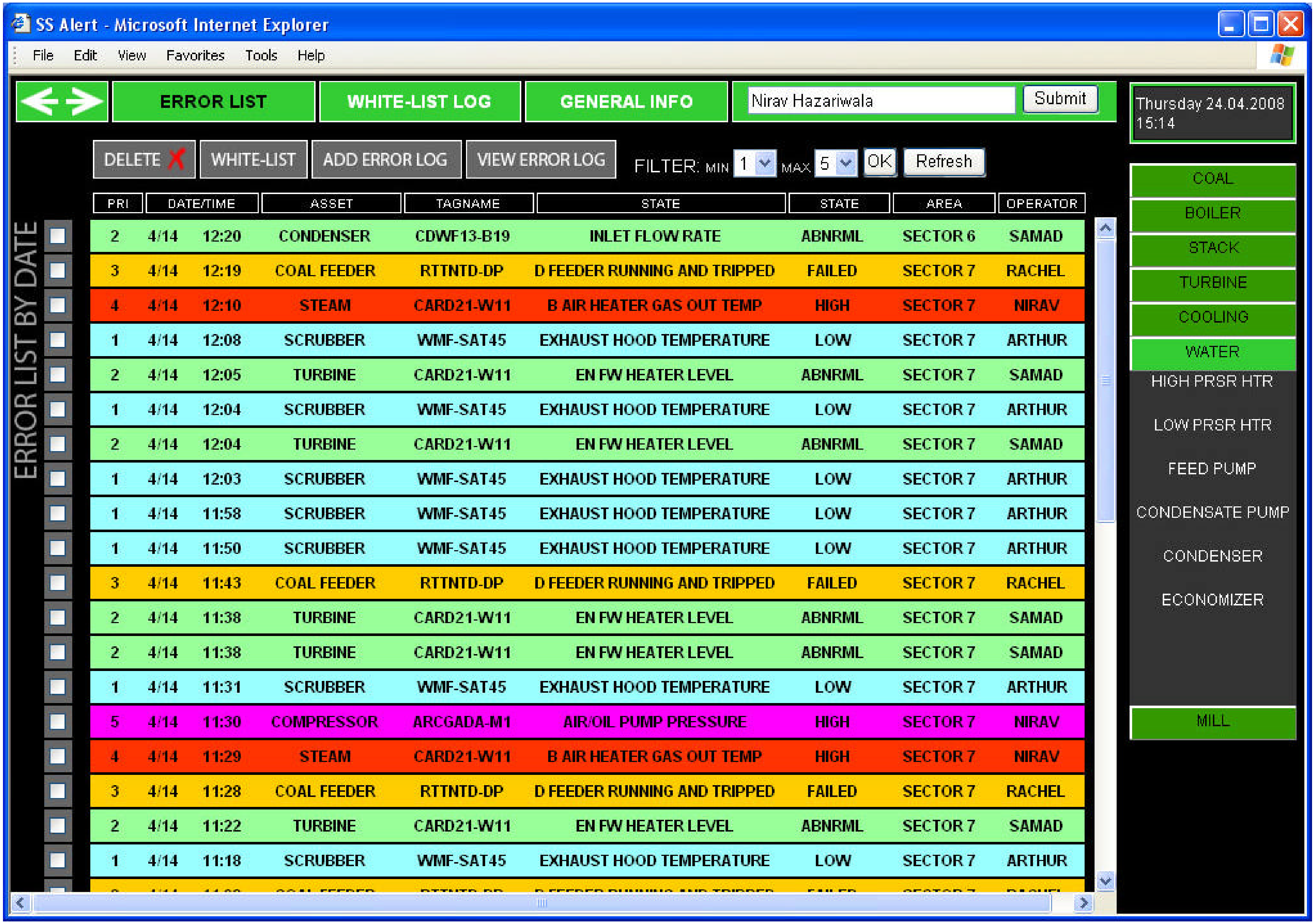


Figure 1: Error Screen (Time sorted)

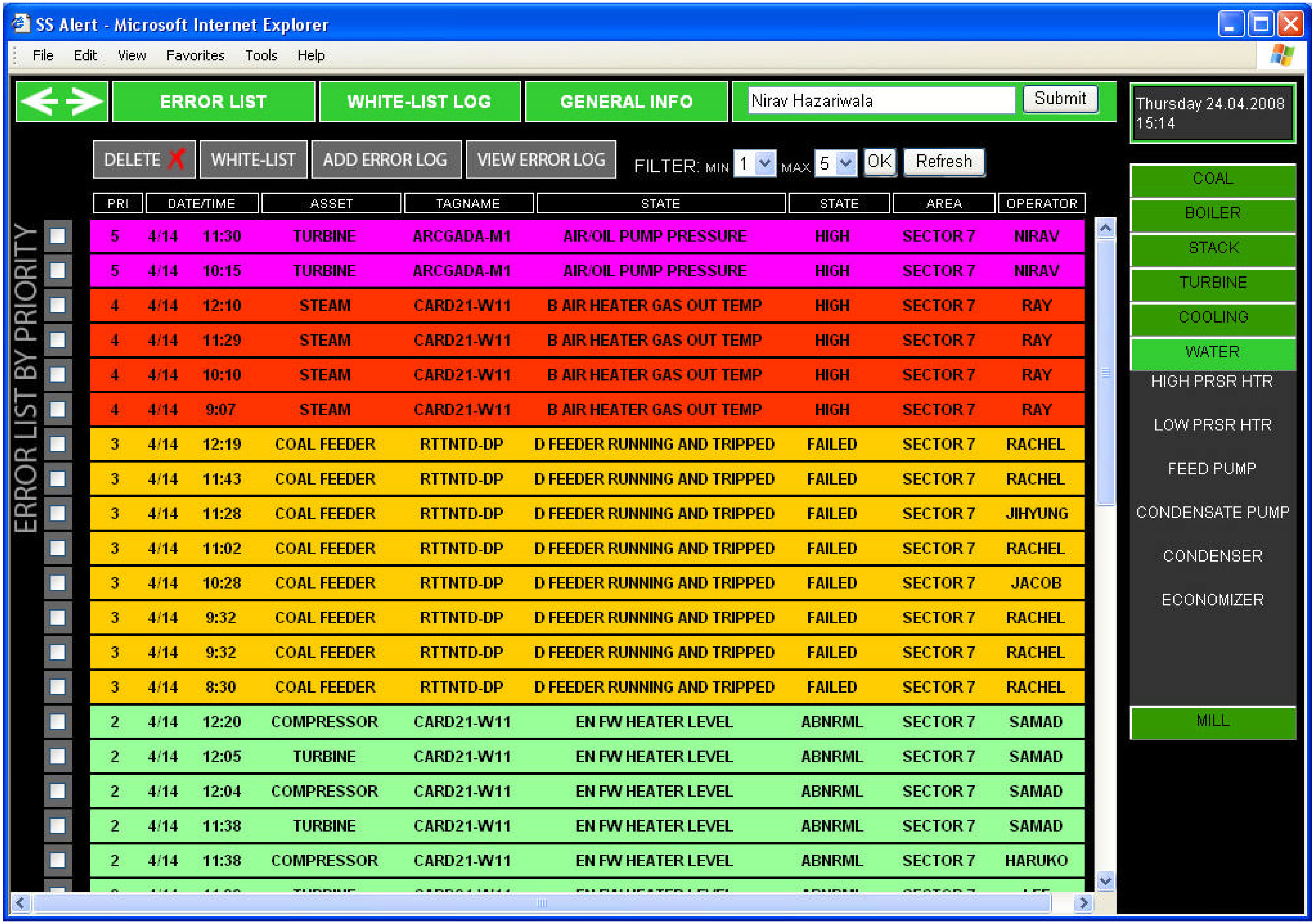


Figure 2: Error Screen (Sorted by Intensity)

Component Screen

Figure 3: Component Screen

This screen above is one of the screens that help to navigate to a specific asset. When a component in the component list of a sector is clicked, as mentioned above, it provides a schematic of the component and some related parts. General information such as temperature and pressure and direction of the flow can be displayed together in the schematic (not included in this example screen). On the left, a list of the components of the schematic is displayed. By clicking a component in the schematic, or by moving your mouse’s cursor over the component list, the certain part in the schematic and its name on the list will be highlighted. This function will help the user determine which component on the list represents the component in the schematic. By clicking on the component on the list, another screen that shows detailed information on the specific asset is displayed. (This will be explained in the next screen shot.)

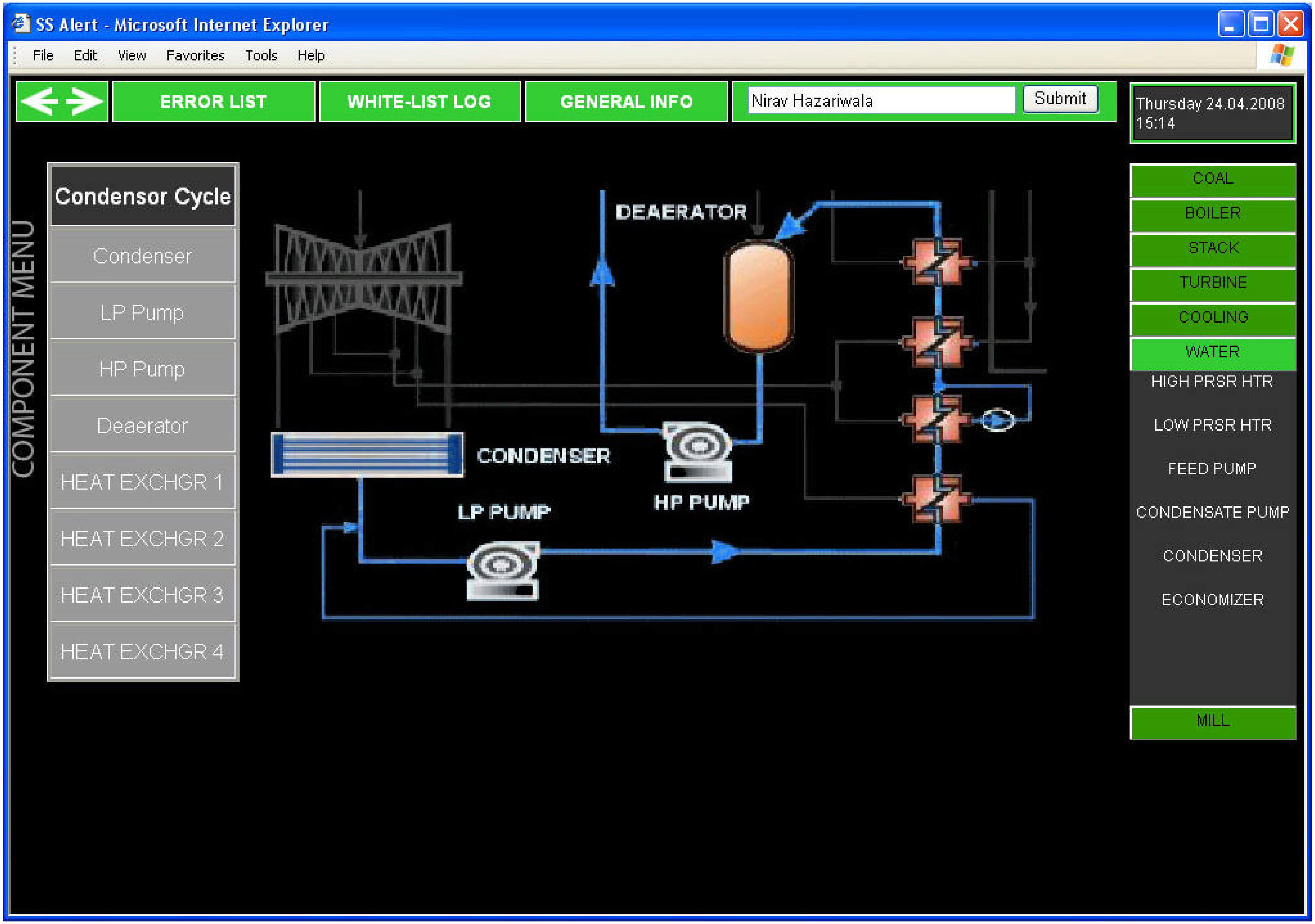


Figure 3: Component Screen

Figure 4: Component Screen

In this particular screen, the component, which was selected from the previous screen above, is displayed. Specific information is displayed on the left bottom. Here a parameters are displayed as needed for example the temperature, pressure, flow rate, and standard value are shown. However, in the real product there should be more detailed and important information provided. The two previous screens demonstrate the ability of the UI to simplify navigation through an area of a sector in which an error has occurred. The screen above can be reached by clicking on the error from the error screen but the navigation allows for the inspection of other components that are interfaced with the error causing component/asset.

This leads to the next option that is directly related to the screen above, the output control. It is a feature that allows the user after analyzing the information on the error to be able to change parameter values and discern a predicted output. This feature also helps to address the issue of a steep learning curve that new power plant employees have to overcome. It provides an option of testing judgment that can then be more justified. An example Component Screen shot is shown below.

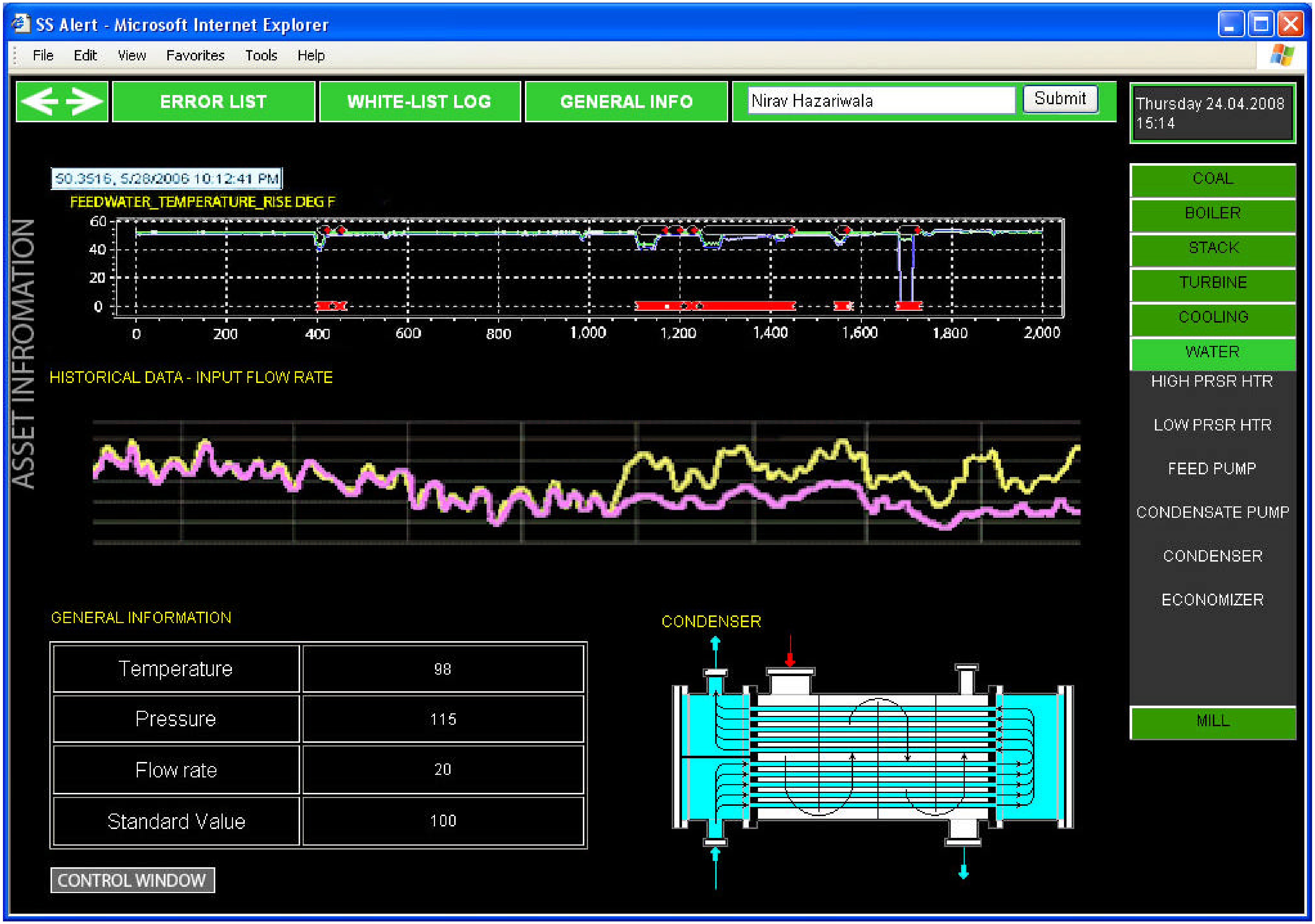


Figure 4: Component Screen

Figure 5: Component Screen

The white-listing option is a very useful tool that can help the end-user to eradicate errors that are deemed phantom or of little consequence. The white-list page contains the plant-wide white-list logs as well as personal white-list logs. The plant-wide log provides the names of other people that have white-listed the same error upon request; the user may then decide to talk to other employees or just be content with the information. It is dual functioning as far as the problem statements are concerned; it helps with communication in the plant as well as aid error reporting. The page contains the personal white-list of a privileged user as well as other varied information. For example, it tells the user how many times an error would have shown up if it had not been white-listed by that user. The white-list page allows the plant supervisor or any other person in the same capacity to completely eradicate an error after it has been white-listed by up to 50% of the privileged employees. A screen of the white-list page is shown below.

Figure 5: Component Screen

Figure 6: White-List Page example

In conclusion, while the User Interface described above does not completely implement all the requirements pre-determined in the design requirements document, it does address some of the key items. A few of the features that were discussed above show how they address the problem statements from an objective view. IN order to further implement the User Interface Design completely more time and a more complete knowledge of how power plants operate is required.

Figure 6: White-List Page example

IPRO 303

Information Design for Plant Management to Predict Equipment Failure

FINAL REPORT, Addendum 3

This Addendum provides a simple cut and paste, unedited record of email and other notes provided by those who visited the power plants. This document serves to capture in raw form, the knowledge gained from these visits. It also includes some emails from Gerald Delaney explaining some screen shots he sent to the team. These screen shots which are of the Bailey Controls UI are also included in this addendum.

Midwest Generation Waukegan Power Plant visited on March 13, 2008.

Midwest Generation Crawford Power Plant visited on April 4, 2008

Subject: [IPRO 303] Plant Tour Thur 3/13
From: Ed Feldy <feldy@iit.edu>
Date: Thu, 13 Mar 2008 17:09:00 -0500 (CDT)
To: doddjac@iit.edu, serogbog@iit.edu, feldy@iit.edu, MDI-ecf@sbcglobal.net, rflemin3@iit.edu, hfujimot@iit.edu, nhazariw@iit.edu, jkim144@iit.edu, slee135@iit.edu, slee116@iit.edu, mcanart@iit.edu, simoray@iit.edu
CC: Rachelfleming@gmail.com, haruko1900@hotmail.com

Class

Only Ray, Jihyung, Nirav and I ended up making this trip. The trip was exceptionally detailed both from seeing the Power Plant where we covered a lot and from a UI POV where the Power Plant engineering manager Mark Nagel and others were very open and because Nirav ended up focusing only on the control room and did not take the plant tour. The Power Plant personnel also allowed us to take many photos.

These are my impressions and notes compiled after the tour. Ray, Jihyung, and Nirav have been chartered to provide you with similar emails generated shortly after the tour so they do not forget important stuff learned and to keep you up to date. Because we are doing this independently there will be some redundancy in our notes. My notes are a chronological record.

Before the tour we went through security which was of the order of airport security without the pass through metal detector. Instead we were individually check via wand. Since the guard house is about a block from the entrance and we were to drive there, the car was also searched including using mirrors to study the underside of the car and opening the hood and trunk. Here we learned that Nirav would not be allowed into the plant proper because he was wearing gym shoes. Thus Nirav was allowed only into the Control Room and Engineering offices. This ended up being efficient because Nirav then focused on our IU questions, interviewing the operators while the rest of us were on the tour.

The tour itself lasted about 2 hours.

The plant structure is ~75 years old but almost all assets are younger. The assets are replaced as appropriate with newer versions or as they wear out. Most of the major mechanical assets like the turbines, generators, boilers etc have ~50 year practical operational life. These assets are large, being of the size of a small house. The plant has multiple of these assets. In hind sight, I did ask for a brochure of the plant but failed to follow up and so do not know if they have one or not, in any case I didn't get one.

As I said, we viewed much of the plant and that is best described viw looking at the photos which I batch *.jpg compressed and downloaded in a *.zip file. Clearly if we need higher resolution *.jpg's, I still have the originals.

In 1995 they upgraded almost all of the control systems in the plant including putting entire plant on a high speed fiber optic network. So their control system including their UI is quiet up to date. They have for example a system where important faults can be text messaged to cell phones. The plant manager who gave us the tour said he field ~5 of these while on the tour.

The plant has roving operators who work in the vicinity of the assets for which they are responsible. (The plant is very large encompassing multiple buildings (although most in one large building) and distances are large in x, y, & z directions. All operation personnel also carry radios which is a primary means of communication to the control room.

The plant operates 24/7 in 3 shifts. There is a shift turnover meeting every 8 hours where important status is communicated and documented. The shift supervisors were 12 hours shifts, I am not sure why this is done? They are currently working on a new project to deal with alarm management. my notes are fuzzy here but they apparently are thinking something about a top 10 alarms system, alarm rationalization? The idea is to have alarms only come to the control room if an action has to be taken, ie info only alarms or self correcting alarms are not highlighted to the control room. Many of the assets are controlled to extent that minor corrections are carrying out automatically.

At the control room they get maybe 1 alarm pre minute. They understand that the Society of Control Engineers (I didn't know there was such a group?) says that 10 alarms per hour is a good number to shoot for. Clearly we have to research this further.

The system put in place in the 1995's were touch screen operated. They have disabled that and now have mouse controlled screens. Located at various places in the plant are local control rooms. These have screens which are the same as in the control room but that only allow monitoring, not changing or controlling of the operation.

The control system they have in place including the primary software for monitoring plant operation is manufactured by Bailey Controls [http://www.abb.com/cawp/seitp161/f05b13130762f1f8c1256de4003c32c3.aspx] [Also I will load a brochure from them into iGroups]. The current interface they have is only a couple of years old.

Individual customization of the interface is NOT good. That is because multiple users are using the same screens and control stations. This is not like your own personal computer. The individuals can select which screens they like to view. There are many screens available to view the same information. These range from simple line drawing with text flow layouts of the assets to text only listing screens. I took many photos of the various screens. There is some commonality in the look and feel for the screens which is like on black, and red indicates a component is "on" or "in service" (not that it is in trouble). All the operators have learned this color code system and refer to screen noting that as they describe the operation of the system.

After the tour and further learning about the control room. We were shown a different set of interfaces that the engineers use. That system is more oriented towards data collection and understanding and does not have a Control function. That system is the one that can be used to program the sending of text messages when a system trigger is surpassed mentioned earlier.

Here they use a different software OSI-PI System [http://www.osisoft.com/] [http://www.osisoft.com/Products/PI%20System/].

This has some of the features that compete with SmartSoft. One thing I noted was a window zoom of graphical data down to the individual data point. This also allows for importing of selected data into secondary tools like MS Excel which the plant manager seemed to like.

end of my notes.

Have a good Spring Break
Ed
==============================
  Professor IPRO 303

Spring 2008 Term
Edmund C Feldy PE
email: MDI-ecf@sbcglobal.net
phone: 847-328-2924
==============================

Notes From 3/13/08 tour of Waukegan Midwest Generation Plant
By: Ray Simons
Date:3/13/08

I just spent 1.5 hours typing my notes into an Igroups email only to completely lose them when I tried to send the email and was told I was no longer logged on. Here is a second, perhaps less detailed attempt.

Before I begin my description I need to say how surprised I was by the state of the monitoring systems. I never expected the level of sophistication we observed. The control room consisted of banks of 8-9 displays reporting the conditions of each unit.

We started by going through a typical post 9/11 security search. They allowed only 1 vehicle on property. They searched my car including undercarriage, trunk, engine compartment and glove compartments.

Mark Nagel, Engineering Manager, took us to his office for a brief intro meeting. Bob Duey, the Station Director stopped in and introduced himself. Ed had the opportunity to tell them about IPRO at IIT.

We started the tour in the oldest section of the plant where turbines 1 through 4 were once housed. It was striking to see the ceramic tile and ornate brass railing. It had to be a beautiful plant in the 1920’s. We then viewed turbines 7 and 8. The two units currently being operated.

Because Nirav had gym shoes on he was restricted to the control room. This served us well because he was able to have a great deal of time asking all of our questions and gaining a great deal of information for our team.

After the turbines we observed the coal handling system. Everything is on a large scale. They burn 4000 tons of coal each day. They unload 200 rail cars of coal per week.

Ed’s photos are probably the best record of the things we saw. But the plant exists on many different levels. The highest is approximately 150 up where the boilers are actually suspended using huge U bolts. Mark walked us throught he entire process.

1995 started a large update. Fiber optics were introduced to connect equipment and controls.

Each generator, 7 and 8 is monitored, run by a Unit Operator. They also have equipment operators who unit operators call to investigate specific alarms. The operators work 8 hour shifts and report to shift supervisors who work 2-12 hour shift. This may be to insure continuity between shifts.

The unit operator gets 1 alarm per minute. Industry standard/goal is 10/hour.

--Power Plant Visit--
Jihyung Kim
March 23, 2008

The power plant was using more than one screen. Therefore there is no limit for putting our information in the screen.

The design and concept was similar to our design. It was based on clicking things to get more specific information. By clicking some categorizes, the user could end up to schematics which showed specific information such as pressure, flow direction, temperature and etc. The user was also able to control the power plant at the same screen.

They had priority level and the errors were highlighted when some serious errors occurred. Also errors were listed in a time sequence order and therefore errors from the past were also accessible.

One another thing that we have to consider is that the power plant does not hire non-experienced people. Three well experienced workers were working there. Therefore it might not be necessary to focus on inexperienced workers for our UI.

However the difference between our design and theirs was that the design they had did not provide any solution for the errors. Therefore it might be something new and competitive against the other companies to provide some solution for the errors which can be based on historical data.

Power plant visit

Hazariwala, Nirav
Ipro 303
3/26/2008

At Midwestern power plant, we got lots of important information about the power plant operations, the (Belly and Pi) system they use and also the GUI for the control room operations to solve different level of errors. I spent about 1.5 hrs at the control room with the operators and supervisor.

During our visit at the power plant got the chance to talk with the control room (unit 7 and unit 8) operators. I found out that they are not the ES but they are operators and follow the instructions from the ES over the phone and help to fix the error through the control room's computers and if some highest level error pops up he lets the ES know about it. They used their work experience to fix the errors. As we discuss in our last class about the control operations, there are 14 computers and about 3000 screens and sub screens they used to control all different machines and processes for the each unit.

They have 5 levels of priority levels for the error depends on the involvements of the process, machine and the most important thing is level of load on the machine or on the process input and output. If some machine or process overloading they consider that error as a highest priority level (doesn't matter with the color for over loading error, over loading is always highest level error). I also found out that priority level is also set on based of the operator and ES experience.

As we can see in the control room pictures, too many errors pops up on the error screen but you can see the same error on the different computer at the same time. Among all these different colors of errors control room operators only take care of the red color (highest priority level errors) errors and some times different colors of error based on their experience as I mention before they have to take care of the first over loading (high input/output etc…) errors. Majority of the time they just ignore the other color of errors or a schedule it for later. I also found out that the lower level errors could change its level and sometimes changes to highest level priority level.

The individual operator has his own choice for the screen (out of about 3000 screens) to look on the all 14 different screens but he also check the other important screens at a same time. For example: boiler, turbine, mill etc… information screens. On the computer screens they have all information about the whole plant. The information provides in the form of graphs, line diagrams, and numerical tables. On the right hand side of the all screens we can see the green tool bar, with the help of that bar they can select any process and machine and get the current all input, output and all other current information. Each machine, process and other related things has their sub menu so we can go to sub menu and try to fix error. For example if they have a error related to the low flow rate of water, so for that they have to click on to the error and the sub menu pops up and they can do some adjustment to fix that particular problem.

The plant has a very good communication system through out the plant. Each employee has their owned walky-talky. They also use internet to email important information through out the plant. If the control room operator see the highest priority level of the error on the screen, he use phone at the unit station to call the related department even the person who can fix the error. Sometimes the department people call to the control room and give them instructions to fix the problem over the phone. The other system they used as a data based is Pi system (I don't have more information about Pi system).

The major problem they are facing is uncontrollable errors flow because on their screens same error is repeated on the different computer screens and unnecessary errors. An unnecessary error means those errors they can't handle for the control room or the lowest priority level error. They would like to distribute all lowest level of error with the related department. I also found out during my conversion with the operator that they don't have any user input interface facility. They also don't have historical solution available for the error. If they have any error they don't have any facility that indicate directly the location of the machine or process at actual error occurred, so while they are in process to solve that particular error they can see couple of more highest level error on the screens. If the same error occurred more then one time in short amount of time during the operator shift and somehow they can't fixed it. They don't have facility to logged the important information in to the computer so the next shift operator has to look at the white board (log board) for the important information.

*** 04/04/2008 Friday
Ed Feldy raw notes Crawford Power Plant Visit

Gerald Delaney (primary person visited) Engineering Specialist responsible for regulatory compliance issues, he is a Chemical Engineer. He has to deal with about 500 regulations some major and significant some small. (For example various water and air emissions down to as small as for example; the City of Chicago has rules regulating the flagpoles and their usage.)

After I explained IPROs and our project as best I could. Gerald said that our project is to broad, that we have to reduce its scope. (This green not emailed to students)

Also joined by John Podaba Engineering Specialist responsible for Electrical Engineering issues, he is an Electrical Engineer.

There are 10 (~) Engineering Specialists at this plant and about 100 employees.

They generously provided pizza and soft drinks for us.

The output of the plant is at 138000 volts which goes to the Commonwealth Edison grid for distribution. (Some transmission not at this location is as high as 138000 volts.) Historically the plant handled some distribution directly and at a lower voltage ~17000 volts. This older system was decommissioned "in place" in ~1998. We were shown this older system for reference and perspective. This old system has an old science fiction lab feeling and seems archaic relative to 1998.

The Engineering Specialist (ES) needs connection to outside programs for information. For example they has many procedures, guidelines, and Technical Instructions (TI's) that they reference often. Those are stored in Lotus Notes. They are audited relative to a PAPER trail by regulatory agencies. Paper is a major responsibility and they see no way around generating many paper documents which must be HAND SIGNED and filed. (In addition they are affected in this way by the Sarbanes Oxley Compliance regulations, which I would not have expected. I would have expected that other regulatory regulations would have transcended Sarbanes Oxley at the engineering level.) They stressed several times about this need for hard copies and the burden of this paper, even to the extent that they must print important emails for records.

It takes 15 years to build a power plant from idea to switch on.

We visited the Control Room which is smaller than the Waukegan room. This room also had the old manual switches and gauges in place and operational. Although they seem to work mostly with the electronic system they expressed that they do use the manual system occasionally and have a real comfort and trust of the older system.

They like Waukegan, have a Bailey Controls hardware and software for the plant control and the PI (Plant Information) system for engineering information.

In the control room they have 9 separate main screens operated by only 3 keyboards and mice, showing the plant operation for each of 2 generators (total 18). There are few other screens around from which they access PI and other. One of those screens had the worst case of screen "burn in" (occurs with CRT or plasma screens) or "image persistence" (occurs with LCD screens) I've ever seen. Clearly this is something that needs to noted in our Requirements Doc because many of these screens are very static. This might affect color choices.

They want to see the current operating data.

They do not like the extra confirm screens that the software forces when that want to do something quickly. e.g. they select an asset, then a pop up forces them to confirm that that is asset they want, they select an action and a pop up forces them to confirm that selected action. They say that the previous generation of Bailey controls used touch screens that went directly to the asset or action desired. I didn't seem that it was the mouse that was their dislike, but rather the extra steps required to do things.

They said that if a person had not worked in the plant for several years they would not be able to interpret or act on the various data on the screens.

They said that the PI system provided information useful for trend understanding.

Old or resolved Errors & Alarms keep "popping" up, they cannot be cleared permanently except by the System Administrator for Bailey Controls (a Power Plant employee). They clearly dislike the fact that these errors stay on the screens beyond their usefulness.

They commented that the graphics showing a plant and or asset layout should all similar assets by the same or similar icon. Thus an small relatively unimportant value will look the same as a large and important valve. (After all they are both valves.) This is like an electrical schematic which really does not give the reader any physical idea of what a component looks like. This might be an argument for a pictorial view or a click to photo option.

The plant tour was similar to the Waukegan tour although not as lengthy or extensive. This facility is maybe 30% smaller but is of the same vintage. The old building is remarkable for its attractive multi-story interior covered in white ceramic tile with details that have an art deco flavor.

Subject: [IPRO 303] Power Plant Visit Notes
From: Arthur Mcanally <mcanart@iit.edu>
Date: Fri, 4 Apr 2008 23:21:21 -0500 (CDT)
To: doddjac@iit.edu, serogbog@iit.edu, feldy@iit.edu, MDI-ecf@sbcglobal.net, rflemin3@iit.edu, hfujimot@iit.edu, nhazariw@iit.edu, jkim144@iit.edu, slee135@iit.edu, slee116@iit.edu, mcanart@iit.edu, simoray@iit.edu

- Operators do not trust the software as much as they do the dials

- White listing needs to be much easier than we were initially thinking, especially for experienced
operators

- Filtering low priorities (e.g. display only >3) is just as important as we were thinking it was

- The direction we need to be focusing is eliminating bad errors. The operator showed us a list of the last
roughly 20 errors, and half of them had been flagged as "false" alarms when actually checked. We might want
to ask SmartSignal directly about this.

04/06/2008
Haruko Fujimoto

Crawford power plant visit note

- It takes a series of steps to end up working in the main control room (first they work at departments of particular parts of the power plant, and when they have enough ideas how whole plant works, they can work at the control room).
- The program uses the color coding system for different levels of errors.
- By clicking the particular asset on the whole plant screen, they can see the asset in more details. They by clicking it again, they can actually control the asset. (They said it takes too much steps to do what they want to do).
- The old Baliey's system actually works better in terms of taking steps to control assets. Some of Baliey's systems are still working at the plant.
- The program often uses one pattern of showing assets even though they are different in sizes and purposes.
- It is possible to keep fault errors from showing up on the screens, but only people with certain knowledge of the computer program can do it (That person is not working at the Crawford plant).
- Even they look though the errors and determined that they are fault errors, those errors keep showing up on the screen every few minutes.
- They do not need to see 90% of the errors on the screen (lower level errors).

Subject: Re: Plant Visit, Crawford Station
From: Gerald Delaney <GDelaney@mwgen.com>
Date: Fri, 18 Apr 2008 06:55:10 -0500
To: MDI-ecf@sbcglobal.net

Professor Feldy, my apology for being hard to reach and unavailable. The attached are the screen prints you requested. The plant asset we chose was the turbine, but every piece of equipment has color indication of whether it's running or off, or electrically disabled. Also some analog type performance indication such as flow produced, temperature, pressure, etc..

The error screens do not "hot link" to anything although we've envisioned that you could link it to troubleshooting support information. Today it's just indication. Color has meaning with low level alarms, through immediate response required.

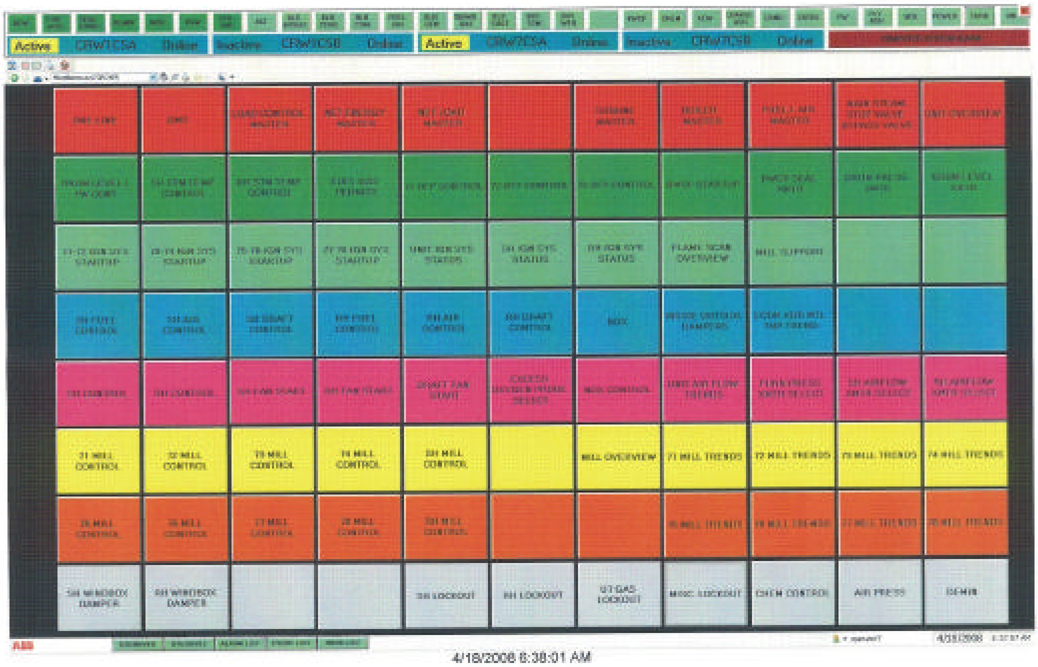
I've also attached a start up graphic that shows circles for each consecutive step for a unit start up. You start at the bottom and progress through lighting each circle on the way up through each major hold point of a typical bring up. Controlled start up and shutdown is a critical element to asset longevity and safety.

(See attached file: 1394_001.pdf)(See attached file: 1394_003.pdf)

Gerald Delaney

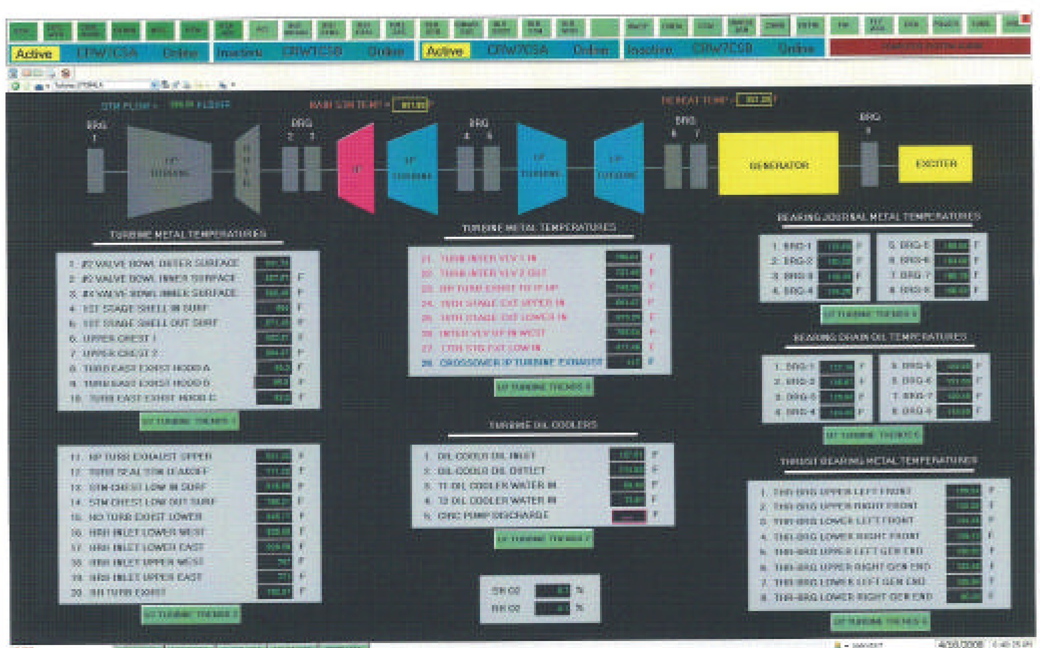
Chemical Process Specialist
Fisk and Crawford Stations
Midwest Generation, LLC
Telephone (773) 650-5443
cell - (773) 447-9467
Gdelaney@mwgen.com

Workplace:Print Screen



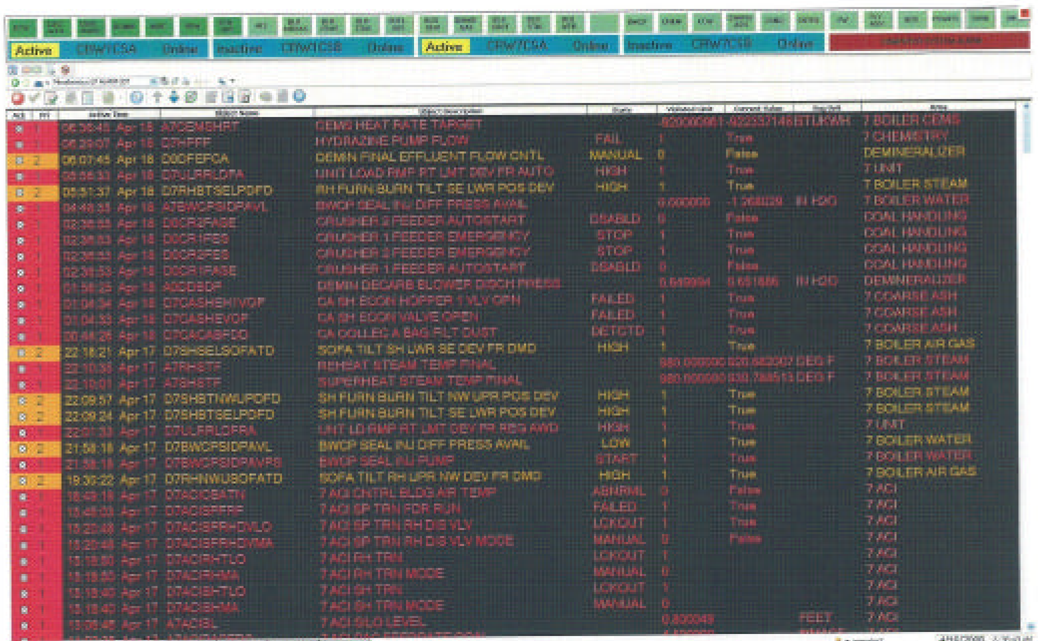
4/18/2008 6:38:01 AM

Workplace:Print Screen



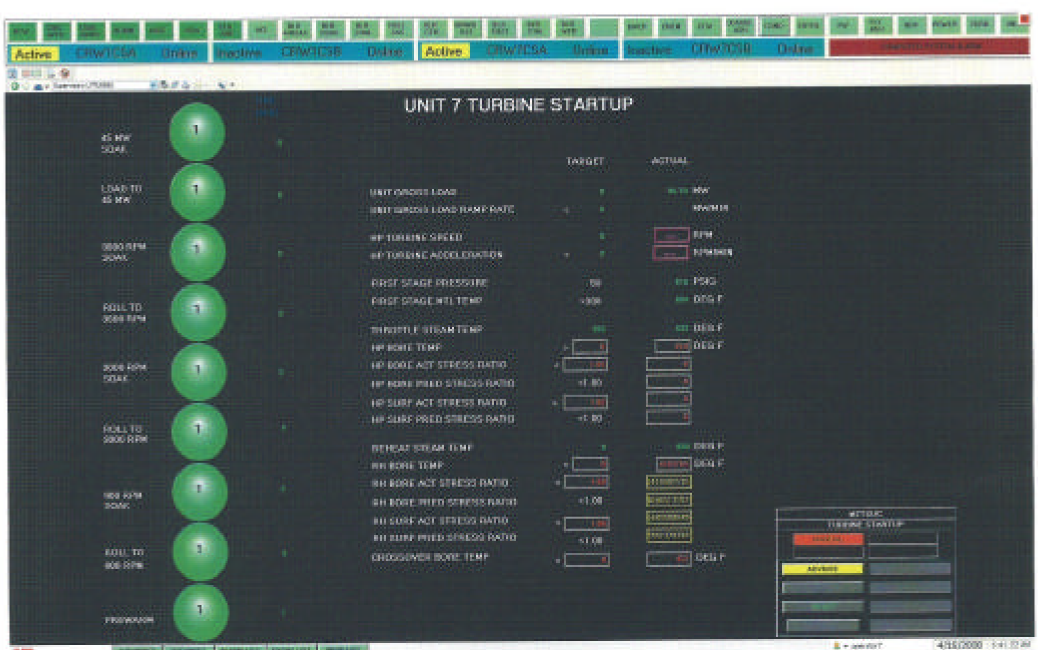
4/18/2008 6:40:29 AM

Workplace Print Screen



4/18/2008 6:38:46 AM

Workplace Print Screen



4/18/2008 6:41:25 AM

```
Subject: Re: Plant Visit, Crawford Station
From: Gerald Delaney <GDelaney@mwgen.com>
Date: Fri, 18 Apr 2008 07:23:47 -0500
To: MDI-ecf@sbcglobal.net

One more thing - The nine active control screens used to be two screens and
was expanded to enable better monitoring.  Each unit operator has the
```

discretion to use the "real estate" as he/she best sees fit. They tend to gravitate to the same screens however.

Gerald Delaney

Chemical Process Specialist
Fisk and Crawford Stations
Midwest Generation, LLC
Telephone (773) 650-5443
cell - (773) 447-9467
Gdelaney@mwgen.com

IPRO 303

Information Design for Plant Management to Predict Equipment Failure

FINAL REPORT, Addendum 4

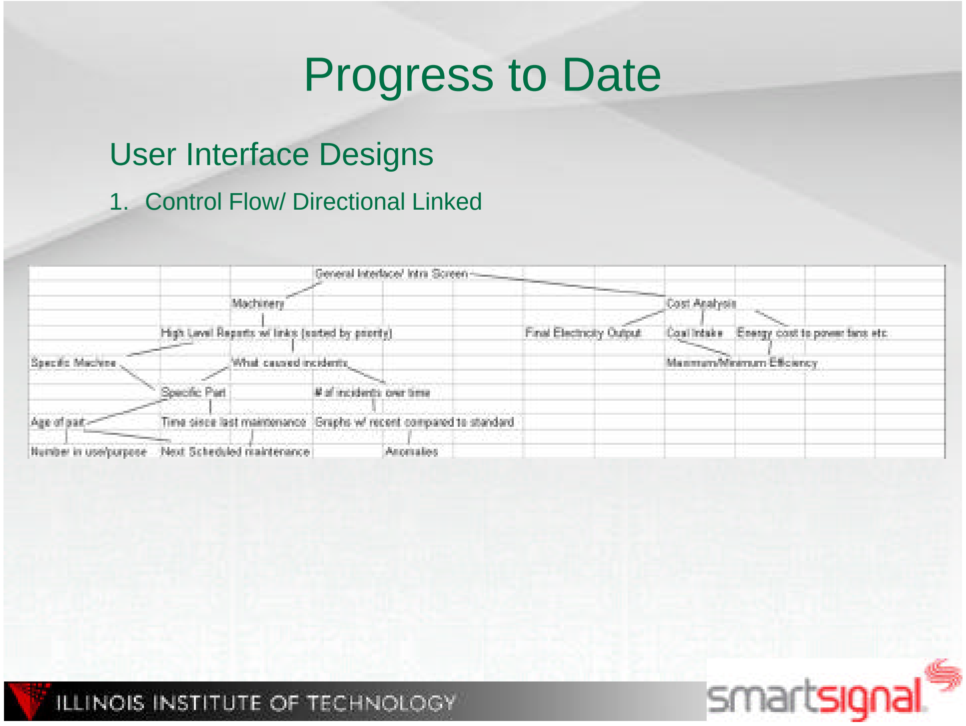
This Addendum provides a simple cut and paste, unedited record of the original 3 User Interface Designs generated for discussion with SmartSignal on Wednesday, March 12, 2008. It captures the IPRO Team's ideas before having visited any Power Plants.

03/01/08
Team1: Arthur Mcanally, Jihyung Kim, Haruko Fujimoto(compiled)

1) **Directionally linked model (by Arthur McAnally)**
The structure starts at the highest level (least technical) with an introduction screen. This splits up into different categories for different people/departments with links to each department. At the departmental level, a listing of errors important to that department is displayed. By clicking on any error, the user comes to a new screen where the machine that caused the error is identified as well as a more technical description of the error. From here the user can then choose to see what specific part is affected, the historical remedies, how many times the error has occurred over a certain time period (e.g. last 6 months). Clicking on any of the listing brings up even more information specific to the request. For example, if the user wants to know more about the specific part, the UI shows the age of the part, the number of them in use throughout the entire power plant (and where), the next scheduled maintenance, and the time since last maintenance. Errors can be deleted after a log entry indicating solution is completed.
The basic idea is to start at the most general level and work closer to finding the specific more technical information. There is quite a bit of overhead since not all of the information is on one screen at one time, but it is the information overload that SmartSignal is trying to avoid.
There is still an issue with how different issues at the same priority are dealt with. As of right now the idea is 8 different levels of precedence. Note that most errors will be 1, but the user is expected to deal primarily with allocation of tasks from 3 and 4. If any issue of level 5 or higher occurs, regardless of where the user is a link to the part and report appears in the corner of the screen.

8-Meltdown if not fixed immediately
7-System will go down if not fixed quickly (brown/blackouts)
6-Legal issues/pollutants not being caught properly
5-User(engineering specialist) should personally take care of immediately
4-Issues that should be checked immediately but does not need engineer to perform check
3-Issues that should be delegated to technicians but does not need immediate attention (checked that day)
2-Ask maintenance to check later
1-Log occurrence, then ignore unless more than 5 of the same incident in a day, in which case notify maintenance
Strength:
- Clear interface
- Gives appropriate information to the appropriate people (does not show unnecessary information on the user interface)
- Separates different amount of work

Weakness:
- navigation overload (takes time to reach the information that end users are looking for)
- Directions misunderstanding (not clear which link to go to get the needed information)
- Does not give the overall picture (since end users are focusing on the specific parts of the power plant, it is difficult to know the context of the errors/ problems)



Screen layout

<Graph of current measured data compared with expected values. Outliers are highlighted.>

Search

By Part Name

By Machine Name

Link | To Intro Screen

To Error Logs

To detailed part info (Age, Primary Use)

To previous Screen

Number of errors in last minute: 8

Average size of error over incident: 4 ft/min

Incident occured at 12:12.3 pm (1 min 23.9 sec ago)

Priority Level: 3

Panic Area (Flashes if priority>=5 occurs)

<Link to error part>

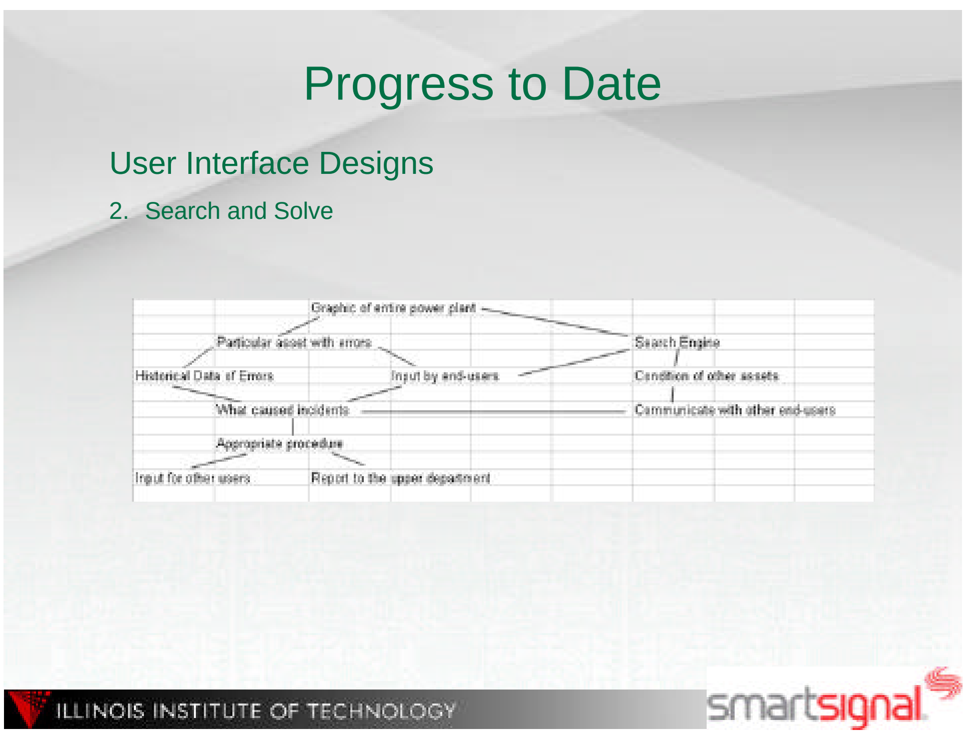
2) **Search and Solve (by Jihyung Kim)**
Including a diagram or a schematic of the entire power plant, a warning or error will be displayed on the screen. The user will be able to click on those errors which will be differently colored as soon as a warning occurs.
Historical data are saved and displayed to compare the current warning and give the user information to determine and examine the error.
The information which will be produced will include the following
-historical data to compare the current failure
-information about related parts which might have caused the failure (Also an option to click the section related to the error can be shown in the entire view for examination).

After the user determines the failure the user is able to contact the appropriate engineer or the technician. Simultaneously, while the user contacts the technician, the information which was examined by the user will be sent together.

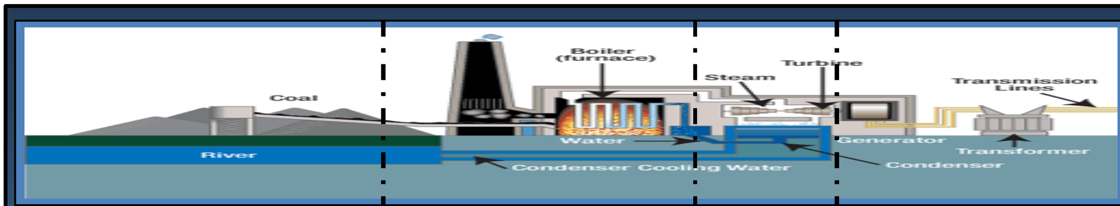
Additional options:
1. The UI includes different user modes. Important errors and warnings should be sent and operated by a professional person. While on the other hand, less professional workers might have access only to less important errors. (Login option)
2. Also providing an option which can control the sensitivity of the sensors would help the user to reduce the errors. So, that less errors will pop up and the user can deal with the more important warnings first. After that the user can set the sensitivity higher so that he can solve with the next level warnings.

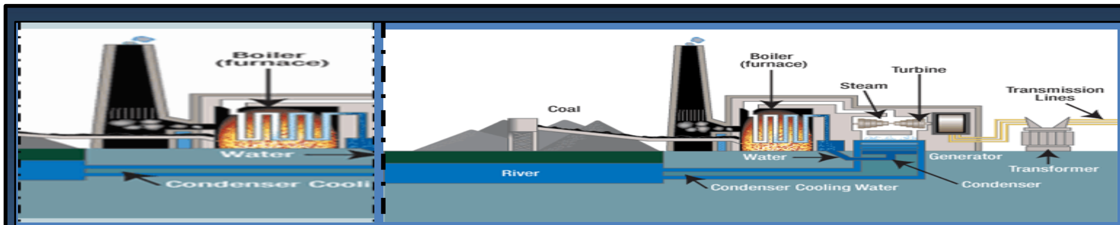
Strength:
- Search feature (end-users can look up the historical data of other sections of the power plant)
- Flexibility (allows individual power plants to set their own design)
- Gives the overall picture of the power plant

Weakness:
- Depends on the historical data and user inputs (it is hard to detect the new cause of the errors)
- Not universal to all users (each end users are working on different user interface)
- Hard to manage (hard to glance the overall conditions of the whole end users)



Screen layouts



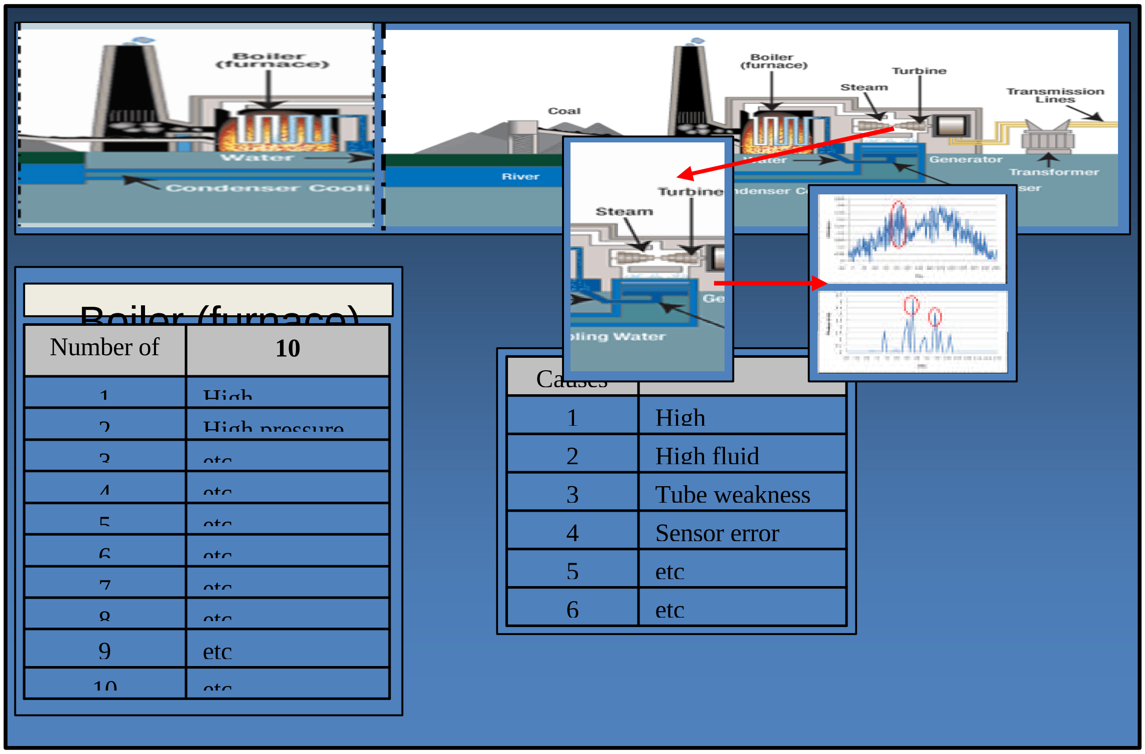


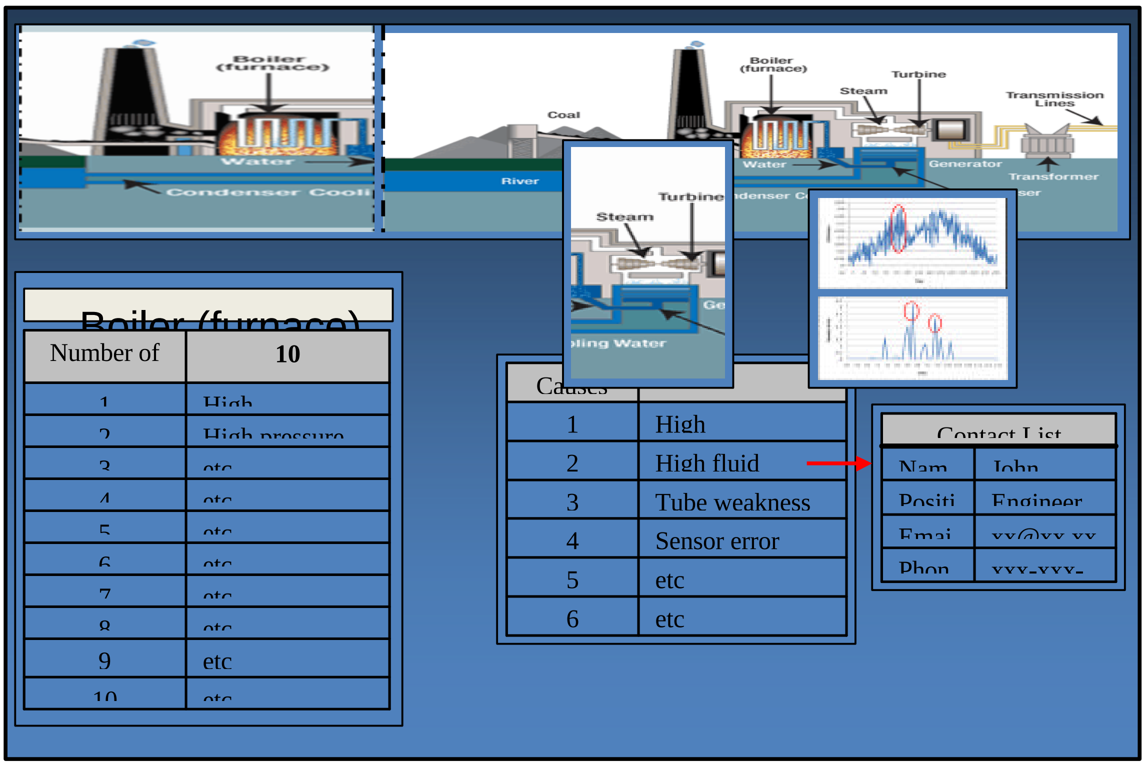
Boiler (furnace)

Number of	10
1	High temperature
2	High pressure
3	etc
4	etc
5	etc
6	etc
7	etc
8	etc
9	etc
10	etc

Histori
cal

Causes	
1	High temperature
2	High fluid
3	Tube weakness
4	Sensor error
5	etc
6	etc


Boiler (furnace)
Coal
Steam
Turbine
Transmission Lines
Water
Generator
Transformer
River
Number of
10
1 High
2 High pressure
3 etc
4 etc
5 etc
6 etc
7 etc
8 etc
9 etc
10 etc
Causes
1 High
2 High fluid
3 Tube weakness
4 Sensor error
5 etc
6 etc

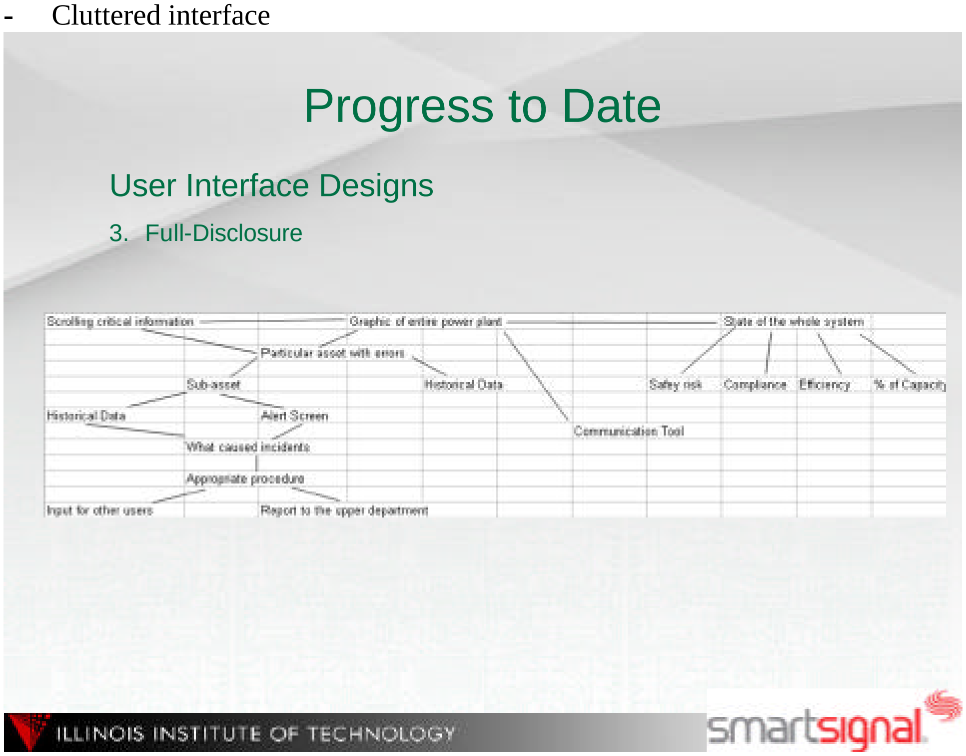

Boiler (furnace)
Coal
Steam
Turbine
Transmission Lines
Water
Generator
Transformer
River
Number of
10
1 High
2 High pressure
3 etc
4 etc
5 etc
6 etc
7 etc
8 etc
9 etc
10 etc
Causes
1 High
2 High fluid
3 Tube weakness
4 Sensor error
5 etc
6 etc
Contact List
Nam John
Positi Engineer
Emai xx@xx.xx
Phon xxx-xxx-

3) **Full-disclosure (by Haruko Fujimoto)**
Home screen shows a graphic of a whole power plant with different colored assets. When an error is detected, the asset color changes to red to indicate trouble. When everything is under control, the assets stay in gray. At the side of the home screen, small window showing the state of systems as a whole can be seen. Some elements included in this window are: safety risk, compliance, efficiency, and % of capacity. At the bottom of the home screen, the most critical information all users should know about will be shown as a scrolling manner. By right clicking an asset, it shows the input and history of the particular asset maintenance. Left clicking an asset leads to sub-asset screen where users can see the asset more detailed level. Generally, sub-asset screen works in the same way as the home screen, while left clicking the sub-asset leads to the alert screen. On the alert screen, the whole sensor details can be seen (the alert screens from SS presentation indicating error-failure steps). Another option that can be added to this UI is the communication tool between different users. This works like iGroups website, where users can upload the files and information they consider valuable for other users as well as sending each other e-mails giving information on the errors and maintenance.

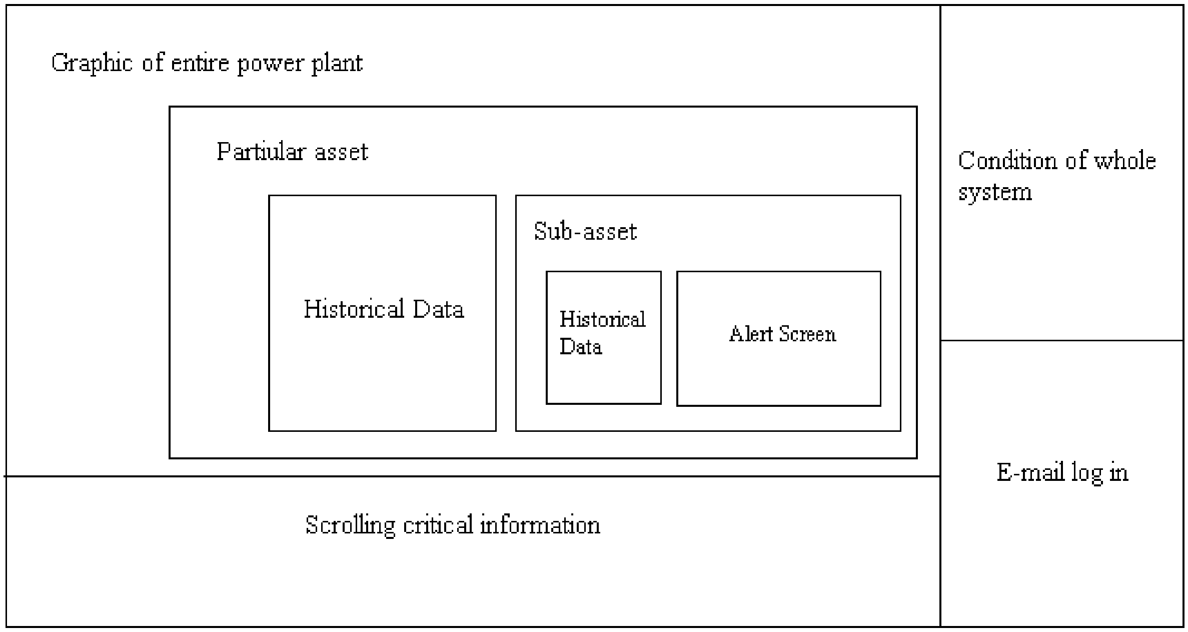
*Since this user interface is similar to 2), idea 2) and 3) are more likely to be combined to one user interface.

Strength:
- Can always get the over all conditions of the power plant
- Direct access to the errors/ problems
- Scrolling (gives the critical error information to all end users)

Weakness:
- Information overload (in need of further categorizing the errors)
- Does not navigate people based on their positions (all end users looks at the same user interface)
- Cluttered interface



Screen layout


Graphic of entire power plant
Partiular asset
Historical Data
Sub-asset
Historical Data
Alert Screen
Condition of whole system
E-mail log in
Scrolling critical information

IPRO 303

Information Design for Plant Management to Predict Equipment Failure

FINAL REPORT, Addendum 5

This Addendum provides a Budget Accounting for IPRO 303, Spring Term 2008.

Original Budget presented in our PROJECT PLAN dated February 22, 2008

IPRO Day	$300 - Presentation board, handouts, visual supplies
Misc.	$150 - Basic supplies, printing
Transportation	$150 - Visiting Power plants and SmartSignal

Total	$600

The IPRO office never provided any written or verbal feedback on this budget. We assumed it was approved, when we received reimbursement for travel expenses. Unfortunately we cannot submit a final accounting at the date of the Final Report because unknown expenses are still outstanding. For example, the IPRO office has encouraged us to visit SmartSignal to provide more information on our work and we have provided possible dates to do this. SmartSignal has not yet responded regarding if this is desired.

Expenses and updated Budget as of April 29, 2008.

IPRO Day	$ 40.00 - Poster Printing (estimate)
Transportation	$160.09 – Mileage Expenses for trips to 2 Power Plants. (charged)
Transportation	$ 50.00 – Mileage Expenses for trips to SmartSignal. (estimate)

Total	$250.09

It is expected that we will be **$ 391.91** under budget.

IPRO 303

Information Design for Plant Management to Predict Equipment Failure

FINAL REPORT, Addendum 6

A nearly complete accounting of time expended on IPRO 303, Spring Term 2008. Note his understates the time allocated because one person did complete their time sheet. Also, this cannot be final because activities are scheduled for after completion of this Final Report.

Notes: Sangkyoung Lee dropped the class.
Jacob Dobbs incorrectly entered the year for the 4/22-2/28 time.
The week 4/27-5/3 is understated because in most case people did not estimate their time for IPRO day.

IPRO 303

Semester Hours Summary

[Click to Print]

User	4/22 - 4/28	1/6 - 1/12	1/13 - 1/19	1/20 - 1/26	1/27 - 2/2	2/3 - 2/9	2/10 - 2/16	2/17 - 2/23	2/24 - 3/1	3/2 - 3/8	3/9 - 3/15	3/16 - 3/22	3/23 - 3/29	3/30 - 4/5	4/6 - 4/12	4/13 - 4/19	4/20 - 4/26	4/27 - 5/3	Semester Total
Raymond Simons					3.4	9.6	6.5	18.5	1.0	14.0	14.5		3.0	7.9	10.0	11.5	25.3		127.2
Niravkumar Hazariwala				4.0	4.3	7.0	10.0	10.5	13.5	7.5	13.0		9.5	10.0	14.0	9.0	4.5	5.0	121.8
Samad Erogbogbo				2.0	3.0	6.0	12.0	9.0	9.0	33.0	6.0		12.0	3.0	6.0	4.0	4.0	3.0	112.0
Sangwook Lee					10.5									6.3	1.0				17.8
Rachel Fleming					6.0	8.5	5.0	4.0		14.0		6.0	6.0	4.5	4.0	3.0	4.0	5.5	70.5
Sangkyoung Lee					4.0	1.0													5.0
Jacob Dodds	1.5			2.0	3.8	1.5	1.5	4.5	7.5	6.8			5.5	3.0	1.5	11.0	10.0	12.0	72.1
Haruko Fujimoto					6.5	6.0	7.5	8.0	6.5	4.0	4.0		2.0	8.0	3.0	22.0	2.0	7.0	86.5
Jihyung Kim					6.0	5.0	5.2	4.2	7.4	8.2	11.9	4.2	5.4	1.0	9.0	11.0		6.5	85.0
Arthur Mcanally				1.5	3.0	4.5	9.0	4.0	10.0	6.5	3.0		3.0	8.0	9.5	5.5	5.0	3.5	76.0
Ed Feldy		3.2	22.4	19.3	23.4	19.1	30.2	29.9	20.2	19.6	31.3	2.3	16.5	24.2	17.5	14.7	21.9	29.6	345.3
Week Average	**1.5**	**3.2**	**22.4**	**5.8**	**6.7**	**6.8**	**9.7**	**10.3**	**9.4**	**12.6**	**12**	**4.2**	**7**	**7.6**	**7.6**	**10.2**	**9.6**	**9**	
Week Total	**1.5**	**3.2**	**22.4**	**28.8**	**73.9**	**68.2**	**86.9**	**92.6**	**75.1**	**113.6**	**83.7**	**12.5**	**62.9**	**75.9**	**75.5**	**91.7**	**76.7**	**72.1**	**1119.2**