IPRO 303

Operational Considerations in Wind Power Generation: Cost Impact of Equipment Failures, and Opportunities for Improved Performance

PROJECT PLAN

Instructor: Edmund C. Feldy PE
Sponsors: SmartSignal
IPRO Team: Olaoluwa Adeola, Christopher Catalina, Jesus Cervantes, Sara Claxton, Samad Erogbogbo, Earl Fairall, Richard Ike, Robert Keane, Kristina Lakiotis, Aaron Melko, Mithun Michael, Viral Patel, Donald Ruffatto
Date: Friday, September 19, 2008

1. Abstract

The Fall 2008 semester of IPRO 303 will investigate and analyze the economic and technical details of the wind-turbine electricity generation industry. The IPRO 303 team will be focusing on the impact of equipment failures that lead to downtime and maintenance associated with the failures. A comparison of current industry practices in dealing with these problems, along with a detailed economic analysis of the true costs involved, will be the major goal. A final report of the findings and conclusions of the IPRO 303 team will be provided to our sponsor, SmartSignal Inc. It is understood that this Project Plan will change as the term progresses and more information becomes available.

2. Background

A. Sponsor Information: SmartSignal Inc. offers software which models machine and equipment behavior, and can learn to distinguish between normal and abnormal conditions. This information is used by machine operators to proactively deal with potential problems before they cause faults and unplanned downtime. It can also be used to determine when preventive maintenance is actually needed, which can reduce costs by limiting unnecessary maintenance. SmartSignal has a long history of providing its products and services to many different industries. It does not currently deal with the wind power industry, but views this area as a potential future market for its products. Developing this market will require an in-depth understanding of the nature of equipment failures and industry maintenance practices, including all economic costs. An accurate awareness of the true costs of faults, planned and unplanned down-time, and maintenance and repair practices is therefore important to understanding the role SmartSignal's products can play in this industry. Equally important is an understanding of the accuracy of current industry perceptions of these costs. IPRO 303 will investigate these aspects of the wind turbine industry and attempt to develop some conclusions which will aid SmartSignal in determining its future role in this area.

B. Addressed Problems: As indicated in the paragraph above about SmartSignal the intention of IPRO 303 is not to solve an existing problem but to help our sponsor come up with an innovative solution that will be more effective than existing solutions. We will investigate if the current maintenance paradigm that exists in the wind-turbine power generation industry is sufficiently efficient.

C. Technology Involved: Technical report writing and computational analysis software will be employed in analyzing the data and information collected as well as reporting the analysis results.

D. Other Attempts to Solve the Problem: SmartSignal personnel are also working on alternative solutions. This is the first attempt by IPRO 303 at solving the problem.

E. Ethical Issues: SmartSignal operates in a competitive market and any classified or sensitive information or documents obtained from SmartSignal will be kept confidential and will not be disclosed to anyone outside the project team. SmartSignal has requested that we not mention their sponsorship of IPRO 303's project when gathering information. We recognize there may be important ethical consequences of this, and plan to examine these as they arise.

F. Supporting Documents: A document provided to us by our sponsor from our initial briefing for the project is attached as addenda A.

3. Objectives

A. Our project sponsor SmartSignal has provided us with the following objectives:

1. Explain faults that are occurring in wind turbines and why
   - Gain a general understanding of how wind turbines work
   - Identify turbine components and major failures
   - Determine turbine faults
   - Determine most costly/most common reasons for turbine downtime
2. Provide detailed overview of current maintenance practices and procedures
   - Provide listings of maintenance procedures available
   - The advantages and disadvantages of current maintenance practices
   - Determine who is responsible for maintenance (i.e. manufacturers or 3rd parties)
3. Technical Business Case
   - Describe the revenues and cost basis of wind power generation
   - Calculate costs of unplanned downtime due to failures

The team expects that these goals may change as the team acquires a better understanding of the project.

4. Methodology

A. Defining the problems

Identifying the cost of failures associated with wind turbine operations to aid in developing preventative turbine failure measures:

- Understand wind-turbine failure modes and their causes
- Understand the current paradigm for maintenance practices
- Cost analysis of wind-turbine power generation

B. Gathering research

Gather research and background information on turbine failures

- Use available wind data resources.
- Contact wind turbine manufacturers, operators, and 3rd party maintenance crews with questions regarding:
  - Turbine faults that occur
  - Staffing, expertise, organizational arrangements of maintenance programs
  - What maintenance is in-house? What's farmed out?

- Turbine manufacturer warranty issues
- Use of technology, tools, and labor to combat unexpected downtime

C. Initial data compilation and analysis

Compilation of results gathered from research:

- Display failures and downtime results with graphs, tables, and spreadsheets
- Use the graphs, charts and (or) spreadsheets to determine which causes of unexpected downtime are most frequent, most costly, or both.

D. Prepare technical business case

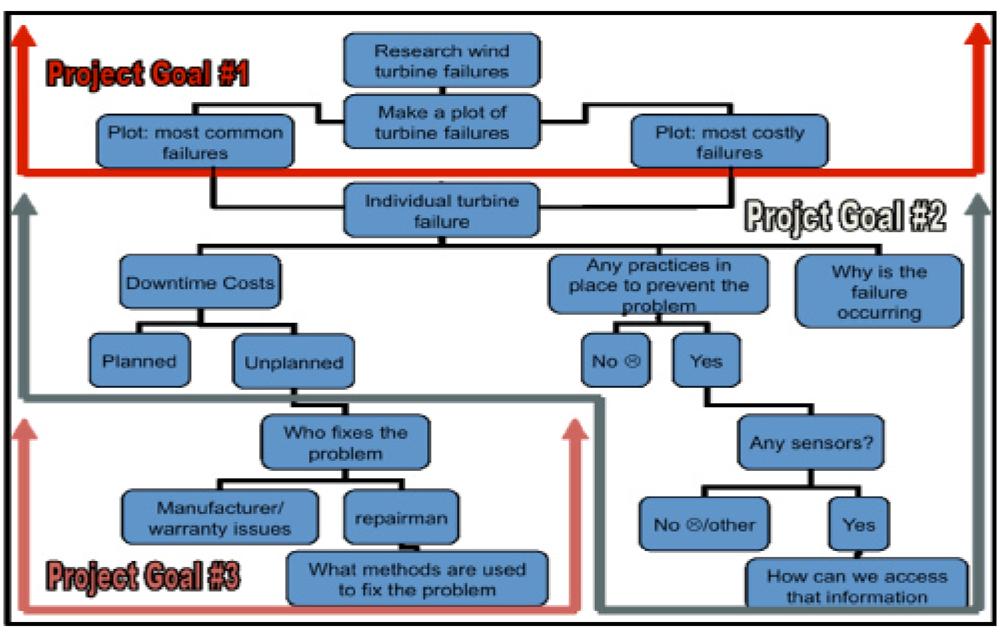
Use the previously compiled data to prepare technical business case

- Define data milestones, and direct focus to them
- Distribute subgroups to data milestones
- Subgroups should determine an answer to these questions (and more as we see fit) for their particular milestone:
  - Costs and comparison of unplanned downtime (due to failure) and planned down time (or in other words- scheduled maintenance)
  - Is a repairman required?
  - What methods are used to fix the problem?
  - Are there any practices in place to prevent the given problem? Can we have access to that information?
  - Why is the failure occurring?

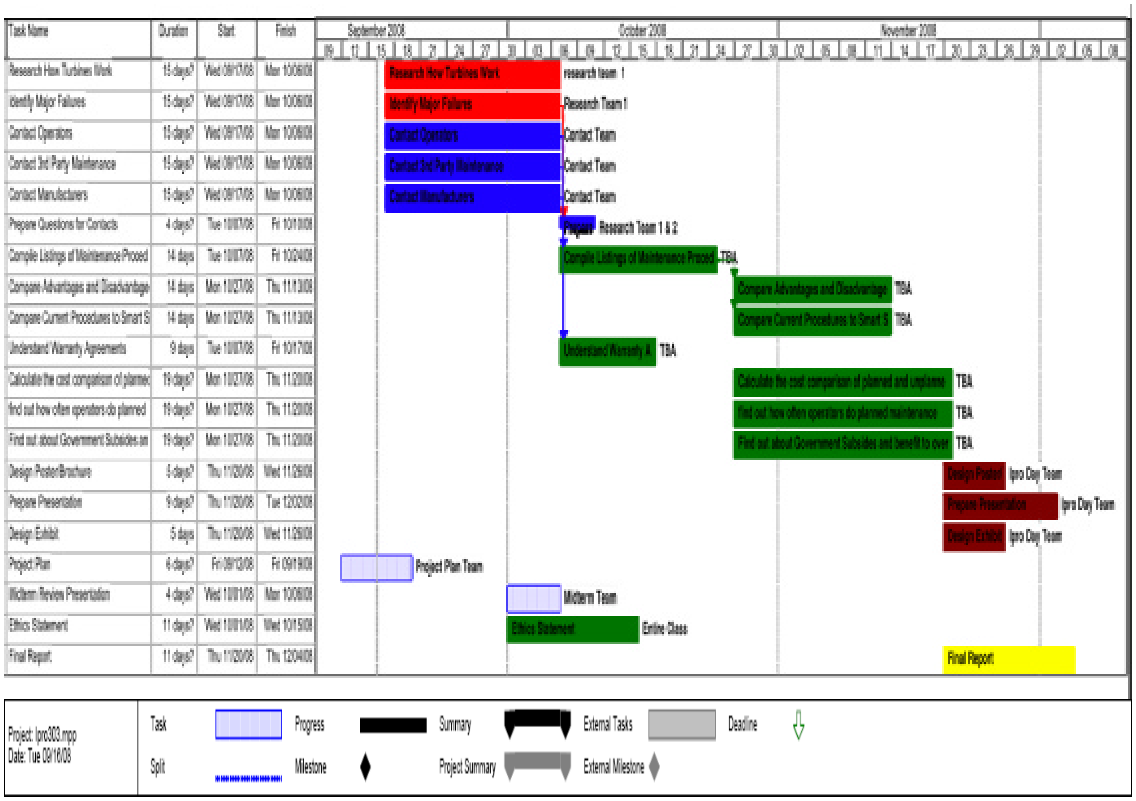
E. IPRO day preparations

Since our project will not be producing a prototype, we will be including in our final presentations and exhibit our results from our semester using the following: graphs/charts/spreadsheets, data milestones, project goals and conclusions.

F. Work breakdown structure



Gantt chart



5. Budget

IPRO Day	$100 - Presentation board, handouts, visual supplies
Misc.	$150 – Food for interviewees
Transportation	$500 - Visiting Wind Farm

Total	$750

6. Team structure and assignments

Name	Major and Year/level	Skills and Strengths	Experience and Academic Interests	Team
Chris Catalina	MSE - Materials Science and Engineering / ME - Mechanical Engineering 4th year	Strengths: Thorough, Work well with others Computer skills: AutoCAD, Pro-Engineer, MATLAB, MS office, C++	-Familiar with mechanical testing of materials have knowledge of basic heat treating principals. -Have an interest in materials processing as well as alternative energy.	Contact
Laolu Adeola	MAE - Mechanical and Aerospace Engineering / Business Administration 3rd year	Strengths: Working with people/working in teams Computer skills: Mac, PC, Linux Microsoft Office, Illustrator, MATLAB, Maple, C++, AutoCAD	-Entrepreneurship	Contact
Viral Patel	AE - Aerospace Engineering / ME - Mechanical Engineering 4th year	Strengths: Punctual Computer skills: MS Office, MATLAB, Pro/Engineer	-Interested in aerodynamics of wind turbines	Research 2
Don Ruffatto	ME Mechanical Engineering 4th year	Strengths: Data analysis/interpretation, problem solving Computer skills: MS Office, MATLAB, Pro/Engineer, Autodesk Inventor	-Researched wind turbines for a previous IPRO -Industry experience in automation -Interested in mechanical design and automation	Research 2
Sara Claxton	AE - Aerospace Engineering ME - Mechanical Engineering 4th year	Strengths: Computer skills: MS Office, DA DISP, Pro/E,AUTOCAD	-Interned at a government company(Internal Ballistic Actuation) -Interested in aerodynamics and blended wing design	Research 2 Deliverables
Earl Fairall	AE - Aerospace Engineering 4th year	Strengths: Technical project leader/coordinator Computer skills: Solidworks	-Interested in mechanical design -Technical Background in electric motors and mechanical systems	Research 2
Mithun Michael	EE - Electrical Engineering 4th year	Strengths: creative, hard working, task oriented Computer skills: MS Office, MATLAB/SIMULINK, PowerSim, PSpice, C++/JAVA	-Interested in grid integration of wind turbines/intelligent control of power systems -Interested in renewable energy technology	Research 1
Jesus Cervantes	ME - Mechanical Engineering 4th year	Strengths: Fixing/Drawing Computer skills:	-Interested in automobiles	Research 1
Samad Erogbogbo	ME - Mechanical Engineering 4th year	Strengths: analytic, problem solving, team projects Computer skills:	-Previous IPRO, -Intern in automotive engineering industry	Research 1
Rob Keane	EE - Electrical Engineering 4th year	Strengths: Computer skills: programming	-Electrical and Electronics Engineering	Research 1 Ethics
Kristina Lakiotis	CS - Computer Science 4th year	Strengths: Computer skills: Programming, graphic programs	-Interested in alternative energy	Research 1 Deliverables Ethics
Richard Ike	ME - Mechanical Engineering 4th year	Strengths: Organization, Problem solving Computer skills: AutoCAD, ProE, Matlab, MS office	-Metallurgical and Mechanical Testing	Contact Research
Aaron Melko	AM - Applied Mathematics / AE - Aerospace Engineering 4th year	Strengths: Data analysis, organization Computer skills: Word, Excel, AutoCAD	-Mathematics -Teaching, Mentoring	Research 2

Tasks

Teams					
Project Plan	**Research 1**	**Contact**	**Research 2**	**Deliverables**	**Ethics**
Chris	Kristina	Chris	Aaron	Sara	Kristina
Laolu	Jesus	Richard	Earl	Kristina	Rob
Samad	Rob	Laolu	Sara		
Richard	Samad		Viral		
Sara	Michael		Don		

Project Plan:
This sub group will be responsible for compiling the sections of this document. They are ultimately responsible for the final appearance and format of this document.

Research 1:
This sub group will be involved in researching how wind turbines work and identifying the major failures that this IPRO team will be focusing on.

Research 2:
This sub group will be in charge of preparing questionnaires for the contact team.

Contact:
The contact team will be responsible for contacting operators, 3rd party maintenance, and manufacturers to schedule interviews.

Ethics:
The ethics team will be considering and analyzing the important ethical consequences of the request by our sponsor to

Designation of Roles

Meeting Roles:

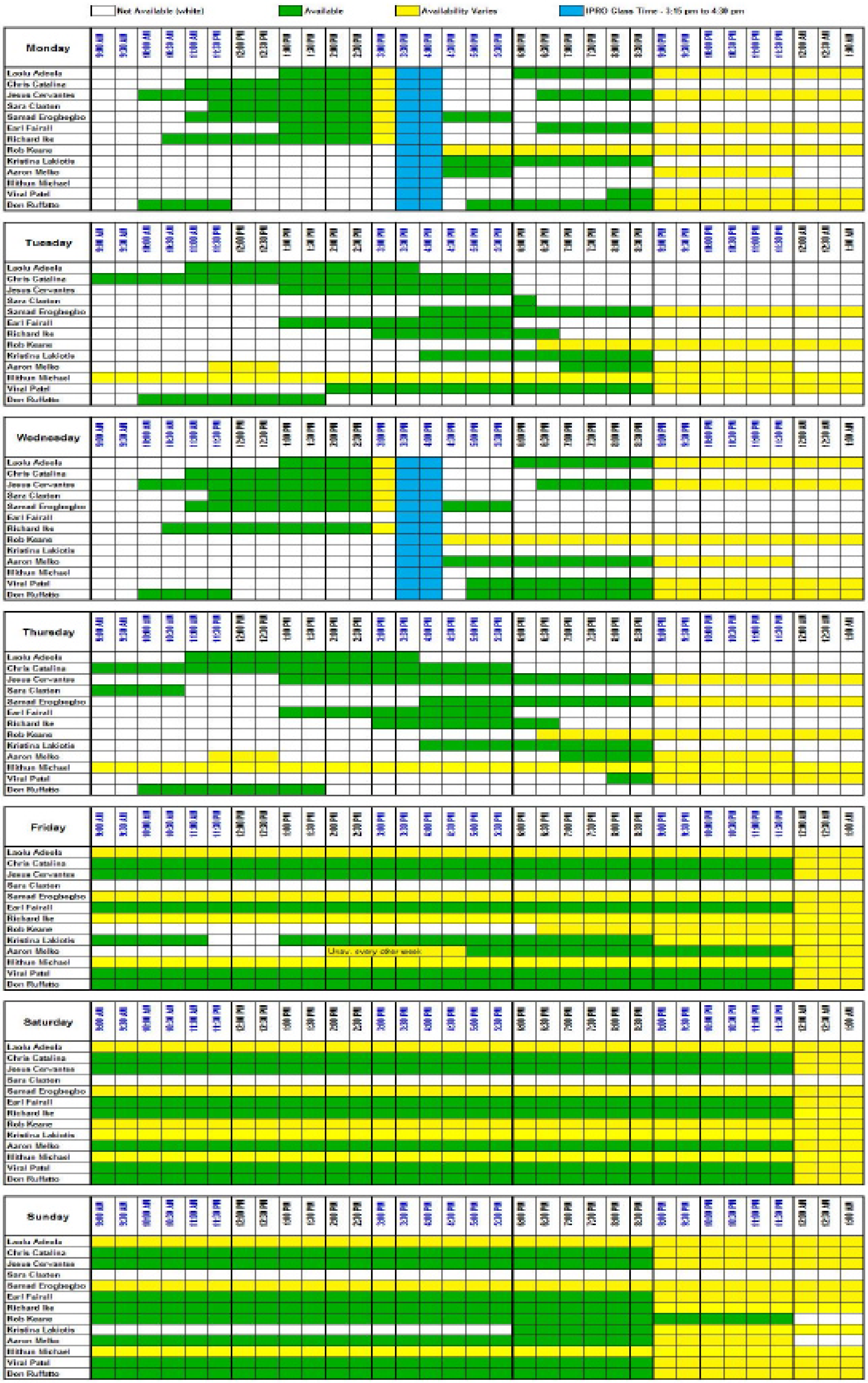
Minute taker:..Entire Team (Via Schedule)
The schedule for minute takers is attached as Addenda B.

Agenda Maker:.....................................Team
Timekeeper: ....None will be assigned

Status Roles

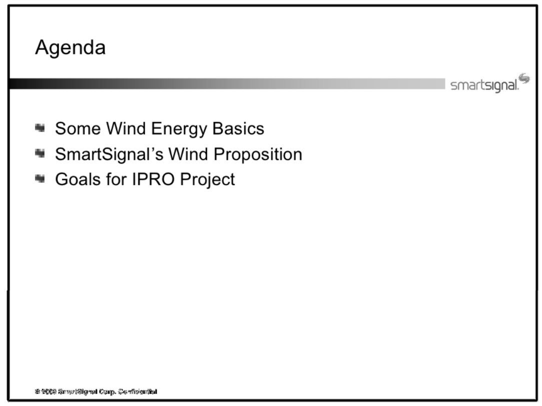
Time sheet collector/Summarizer ....To be determined
Master Schedule Maker: ....Sara Claxton
iGroups coordinator:..............................Samad Erogbogbo – Managing files
....Sara Claxton – Managing e-mails

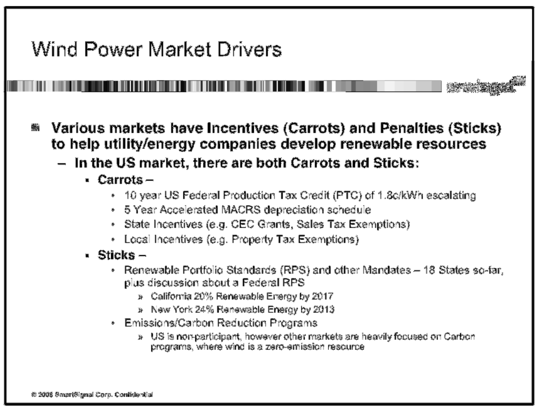
A team leader has not yet been designated but the need for that formal assignment will be addressed in the next couple of weeks.

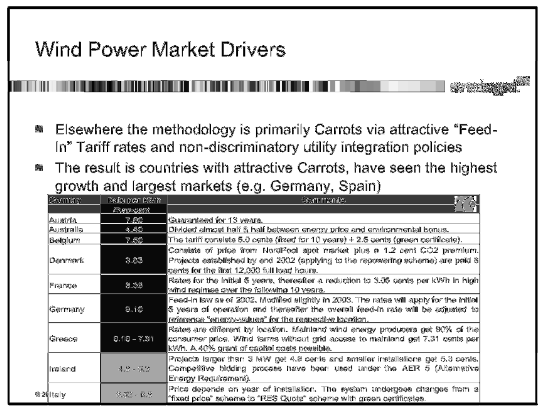

Not Available (white)
Available
Availability Varies
IPRO Class Time - 3:15 pm to 4:30 pm
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
Laolu Adeola
Chris Catalina
Jesus Cervantes
Sara Claxton
Samad Erogbegbo
Earl Fairall
Richard Ike
Rob Keane
Kristina Lakiotis
Aaron Melko
Mithun Michael
Viral Patel
Don Ruffatto
Unav. every other week

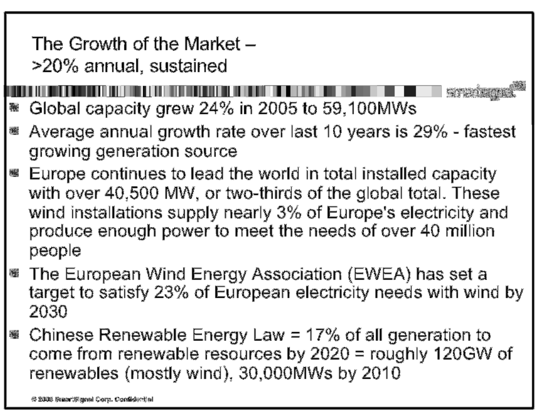
Addenda A

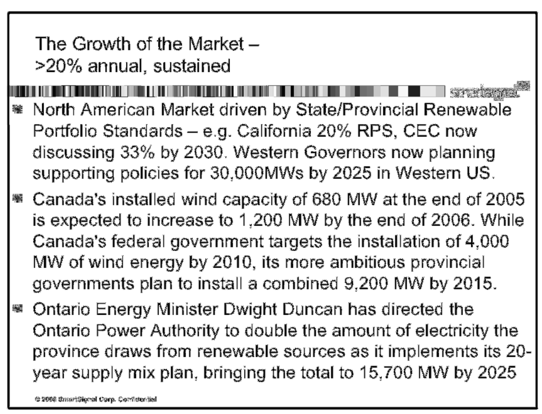
The following are viewgraphs from the initial project presentation given to our team by our sponsor:







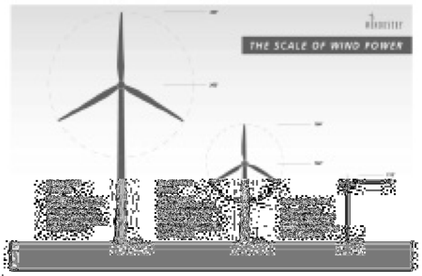




A Typical Modern Wind Turbine

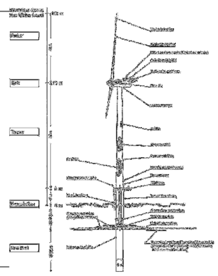
- There are four main categories/classes of wind turbines supplied today, generally considered 4th or 5th generation technology
- The “Mainstream” and “MW-Class” turbines are primarily installed in on-shore environments
- The “Multi-MW Class” are targeted for offshore environments
- From a data perspective, they are nearly identical, just different scale

Scale Examples



Example Wind Turbine

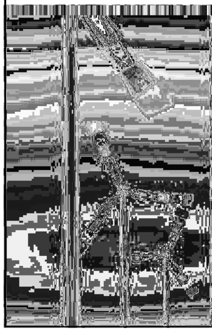
- Vestas V80 – 2MW Wind Turbine
- Rotor Diameter – 80 meters
- Hub Height – 70 meters
- Weights – Blades 6.5 Tons, Nacelle 79 Tons
- Wind Speeds:
  - Cut-in = 4 meters/second (8.95mph/Class 3 “Beaufort” Gentle Breeze)
  - Rated Output = 13 meters/second (29.08mph/Class 6 “Beaufort” Strong Breeze
  - Cut-out = 25 meters/second (55.923mph/Class 10 “Beaufort” Whole Gale)



Data Overview

- Turbine Controller/PLC provides between 350-1200 tags, dependent upon what manufacturer “publishes” in protocol.
  - Mostly digital, typically approximately 50-60 Analog values
- Some manufacturers publish controller protocols (e.g. Mitsubishi). Others consider highly proprietary (GE, Suzlon, Vestas, Siemens, Gamesa)
- Most Manufacturers require their SCADA for warranty:
  - GE, Bonus/Siemens, Vestas, Gamesa, Suzlon. Mitsubishi is the exception
  - Typically provide customers access to post-processed 10-minute records in SQL/Access.
  - Some offer subset of data in OPC-Server capabilities (for additional cost) for customers that want real-time high-res data (e.g. GE, Vestas, Bonus)

SmartSignal Wind Availability & Performance Solution

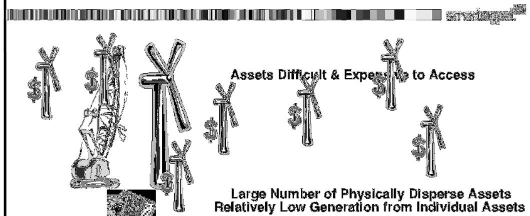


Increase Profitability and Simplify Operations with the Predictive Analytics Leader

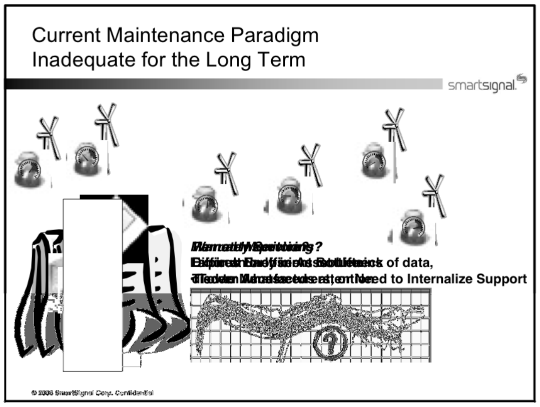
Predict…
Diagnose…
Prioritize…

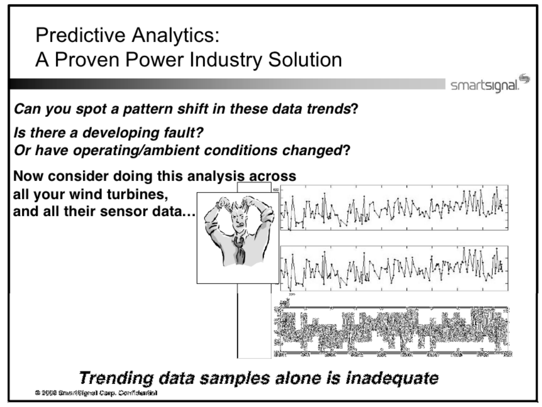
ELIMINATE FAILURE

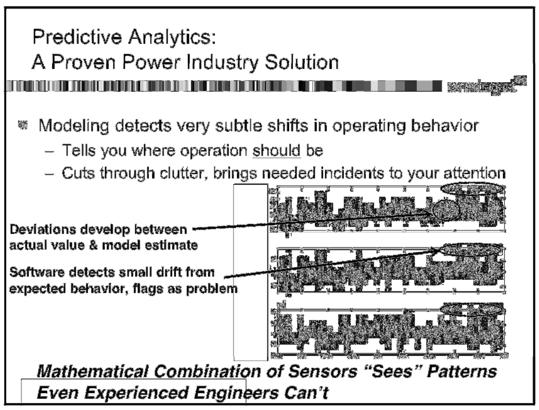
Wind Industry Operating Challenges: A Whole Different Set of Economics

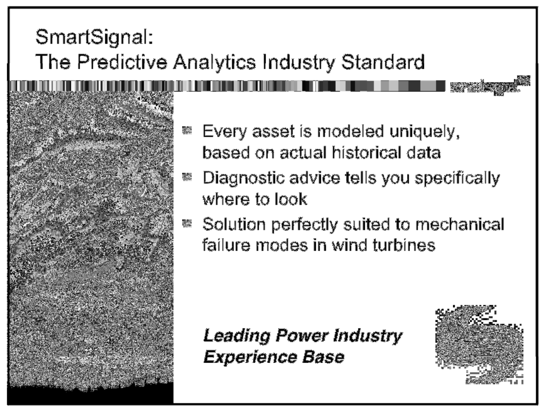


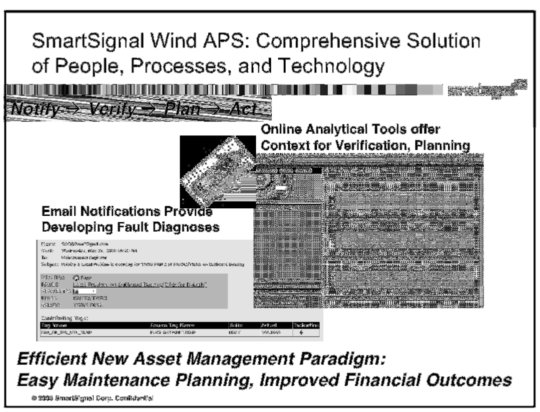
For Viable Wind Power Economics: Availability is King!!!

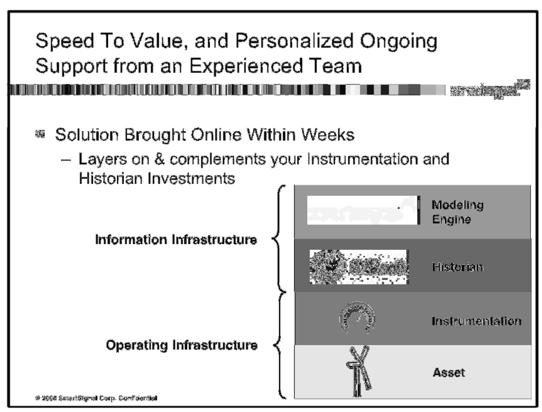

Current Maintenance Paradigm
Inadequate for the Long Term
smartsignal
of data,
Need to Internalize Support


Predictive Analytics:
A Proven Power Industry Solution
smartsignal
Can you spot a pattern shift in these data trends?
Is there a developing fault?
Or have operating/ambient conditions changed?
Now consider doing this analysis across
all your wind turbines,
and all their sensor data…
Trending data samples alone is inadequate


Predictive Analytics:
A Proven Power Industry Solution
Modeling detects very subtle shifts in operating behavior
– Tells you where operation should be
– Cuts through clutter, brings needed incidents to your attention
Deviations develop between actual value & model estimate
Software detects small drift from expected behavior, flags as problem
Mathematical Combination of Sensors "Sees" Patterns
Even Experienced Engineers Can't


SmartSignal:
The Predictive Analytics Industry Standard
Every asset is modeled uniquely, based on actual historical data
Diagnostic advice tells you specifically where to look
Solution perfectly suited to mechanical failure modes in wind turbines
Leading Power Industry
Experience Base

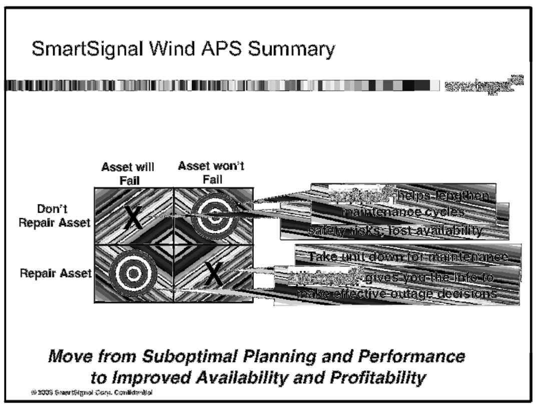

SmartSignal Wind APS: Comprehensive Solution
of People, Processes, and Technology
Notify → Verify → Plan → Act
Online Analytical Tools offer
Context for Verification, Planning
Email Notifications Provide
Developing Fault Diagnoses
Efficient New Asset Management Paradigm:
Easy Maintenance Planning, Improved Financial Outcomes


Speed To Value, and Personalized Ongoing
Support from an Experienced Team
Solution Brought Online Within Weeks
– Layers on & complements your Instrumentation and Historian Investments
Information Infrastructure
Modeling Engine
Historian
Operating Infrastructure
Instrumentation
Asset

SmartSignal Wind APS Summary

- Move from Reactive to Proactive Maintenance
  - Have key issues of importance brought directly to your attention
  - Receive diagnostic advice
  - Receive analytical support from our staff and online tools
  - Receive Equipment Performance Intelligence through processes that integrate seamlessly into your workflow

Adding Insight to Raw Data, Addressing Core Wind Asset Management Challenges

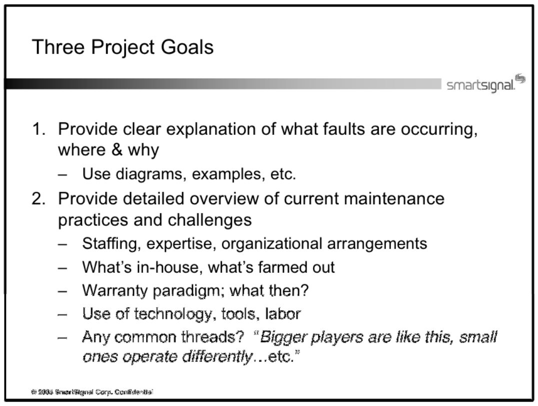


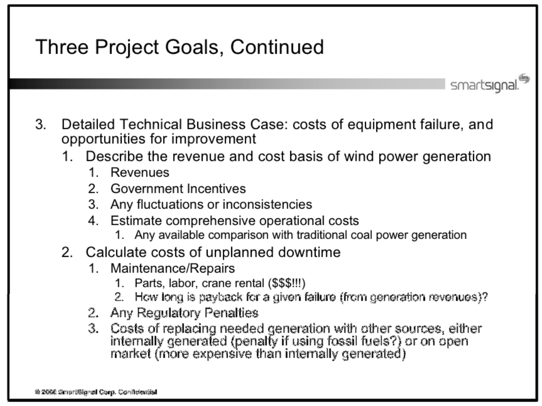
Wind Industry Players & Resources

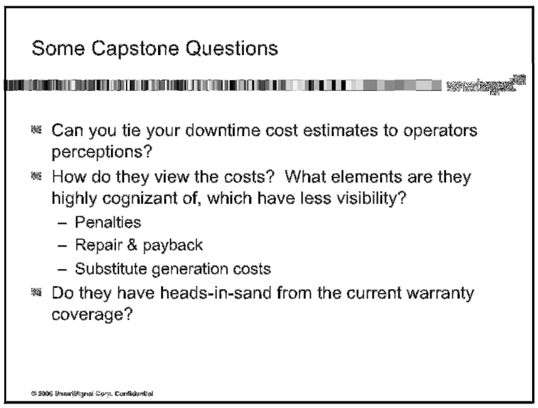
- Owner/Operators
  - Florida Power & Light is biggest in US
- Manufacturers
  - GE, Vestas
- Information Infrastructure
  - OSIsoft
- Service Companies
  - enXco
- Trade Magazines
  - Wind Power Monthly, North American Wind Power
- Advocacy Groups
  - AWEA, American Wind Energy Association
  - Danish Wind Energy Association
    - http://www.windpower.org/en/tour/wtrb/comp/index.htm
- Ancillary players
  - Trucking companies, component manufacturers, site developers…

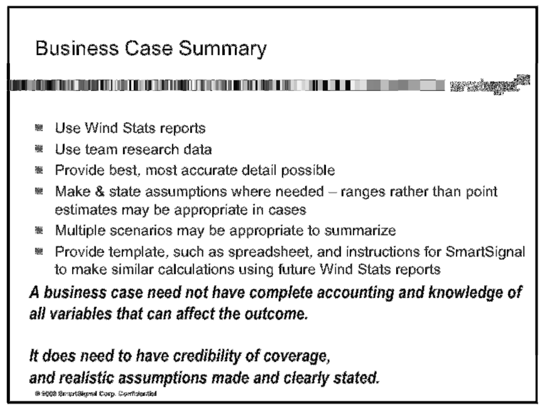
Project Input Information Sources

- Contact industry players
- Literature & web resources
- Wind Stats data report









Addenda B

This following is a tabular representation of the schedule of minute takers:

IPRO 303 Fall 2008
Power Generation: Cost Impact of Equipment Failures, and
sponsor: **SmartSignal**
meets: **Mon & Wed from 15:15 to 16:30**
meets at: **IGTC 3424 S State, rm 4C4-1**
I'm at: **3424 S State, Suite 4001 South**

				Class	MEETING MINUTE OWNER	
8/27/08	Wednesday	Wed	We	1	none	
9/1/08	Monday	Mon	Mo	2	none	
9/3/08	Wednesday	Wed	We	3	none	
9/8/08	Monday	Mon	Mo	4	Ed Feldy	
9/10/08	Wednesday	Wed	We	5	Laolu Adeola	
9/15/08	Monday	Mon	Mo	6	Chris Catalina	
9/17/08	Wednesday	Wed	We	7	Jesus Cervantes	
9/22/08	Monday	Mon	Mo	8	Sara Claxton	
9/24/08	Wednesday	Wed	We	9	Samad Erogbogbo	
9/29/08	Monday	Mon	Mo	10	Earl Fairall	
10/1/08	Wednesday	Wed	We	11	Richard Ike	
10/6/08	Monday	Mon	Mo	12	Rob Keane	
10/8/08	Wednesday	Wed	We	13	Kristina Lakiotis	
10/13/08	Monday	Mon	Mo	14	Aaron Melko	
10/15/08	Wednesday	Wed	We	15	Michael Michael	
10/20/08	Monday	Mon	Mo	16	Viral Patel	
10/22/08	Wednesday	Wed	We	17	Don Ruffatto	Don, you lucked out du
10/27/08	Monday	Mon	Mo	18	Laolu Adeola	But you then become
10/29/08	Wednesday	Wed	We	19	Chris Catalina	If somebody who is s
11/3/08	Monday	Mon	Mo	20	Jesus Cervantes	This may happen mor
11/5/08	Wednesday	Wed	We	21	Sara Claxton	
11/10/08	Monday	Mon	Mo	22	Samad Erogbogbo	
11/12/08	Wednesday	Wed	We	23	Earl Fairall	
11/17/08	Monday	Mon	Mo	24	Richard Ike	
11/19/08	Wednesday	Wed	We	25	Rob Keane	
11/24/08	Monday	Mon	Mo	26	Kristina Lakiotis	
11/26/08	Wednesday	Wed	We	27	Aaron Melko	Actually, some of these
12/1/08	Monday	Mon	Mo	28	Michael Michael	So you like Don abou
12/3/08	Wednesday	Wed	We	29	Viral Patel	Last person first, i.e.
12/5/08	Friday	Fri	Fr		IPRO DAY	
12/8/08	Monday	Mon	Mo	30		
12/10/08	Wednesday	Wed	We	31		