IPRO 303
WIND POWER GENERATION:
COST IMPACT OF EQUIPMENT FAILURE

OVERVIEW

Fall 2008 Summary

- Our sponsor, SmartSignal gave the team objectives to work on over the course of the semester
- The team's objectives focused on the cost impact of equipment failure in large scale wind farms
- To maximize productivity, our group divided into different teams as the semester progressed
- Initial research was carried out to learn about the wind power industry
- Research was also done to learn how wind turbines worked
- The different types of wind turbine failures were classified
- Contact was made with wind farm operators and companies throughout the semester
- The research was used to create cost analysis spreadsheets

Sponsor information: SmartSignal

- SmartSignal offers software which models machine and equipment behavior
- Their software is used to help detect equipment failures before they become problematic
- SmartSignal would like to expand its market to the wind power industry
- SmartSignal has asked the IPRO 303 team to research and analyze the costs associated with the wind industry

IPRO Approach

SmartSignal provided our IPRO with three objectives. Below is a how they and our IPRO objectives were accomplished over the course of the semester.

Objectives
- Explain the how wind turbines work and fail
- Provide an overview of maintenance practices
- Prepare a technical business case

Gather information
- Research using library and Internet sources
- Establish contacts for interviews

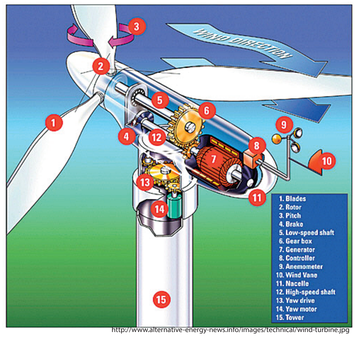
Organize
- Focus Goals
- Analyze Research
- Have interviews

Compile Data
- Create spreadsheets
- Prepare final report

Finalize
- IPRO Day Deliverables
- Present final report to SmartSignal

Wind Turbines Types

- **Small turbines**
  - Used for homes and remote locations.
  - Can act as isolated power systems for households
- **Medium turbines**
  - Used for when small turbines are not powerful enough.
  - They can provide between 20kW and 300kW of supplied power
- **Large turbines**
  - Are complex systems and are usually part of a wind farm.
  - They produce power in MW range.
  - An example of a large turbine is the Enercon, E-126, a model that can output 6MW, and is 135 meters tall.



http://www.alternative-energy-news.info/images/technical/wind-turbine.jpg

Turbine Cut-away

Wind Turbine Components

- **Low speed shaft:** the turbine rotor runs this shaft (usually 30-60rpm)
- **High speed shaft:** this shaft drives the generator via a step up gear.
- **Brake:** Stops the rotor in an emergency.
- **Gearbox:** gears connect the low speed shaft to the high speed shaft
- **Nacelle:** Sits on top of the tower, and includes the gearbox, high and low speed shafts, generator, controller, and brake system.
- **Pitch:** Blades are turned out of the way of the wind direction when wind speeds are too high or low in order to regulate rotor speed
- **Yaw Drive:** Orients the turbine in the direction of the prevailing wind. A yaw motor powers the drive mechanism.
- **Wind Vane:** Measures the wind direction and communicates to the yaw mechanism
- **Tower:** The control and electrical systems are located inside the tower

Cost Analysis Spreadsheets

Our cost analysis is presented as user interactive spreadsheets

- **There are two sets of spreadsheets that show the calculations of the various costs associated with wind turbines including:**
  - The cost of turbine failures
  - Ownership costs
  - The profit of wind turbine output
  - The amount of energy produced
- **One focuses on a single wind turbine**
  - Provides yearly figures
  - Calculates net income of the wind turbine
- **The other spreadsheet focuses on a wind farm**
  - Can support multiple types of turbines in a single farm
  - Provides wind farm's total operational cost hourly
- Users can enter in their own figures to set up different scenarios
- The users are provided with initial figures and help text to use the spreadsheets effectively

Wind Turbine Failures

Wind turbines are complex systems, where every component must function. When failures occur, the turbine cannot operate or produce energy. Failures depend on wind turbine size, geographic location, and manufacturer

- **Gearbox failure**
  - Problems with the bearings and the gears cause failures
  - Monitoring and scheduling routine oil changes can help prevent failure
  - Not as common as other failures, but it is the most costly
  - Replacing one can cost more than120,000 dollars for a 660 kW turbine
- **Other major failures can occur in the:**
  - Electrical systems
  - Sensors malfunction
  - Control systems
  - Blades and pitch

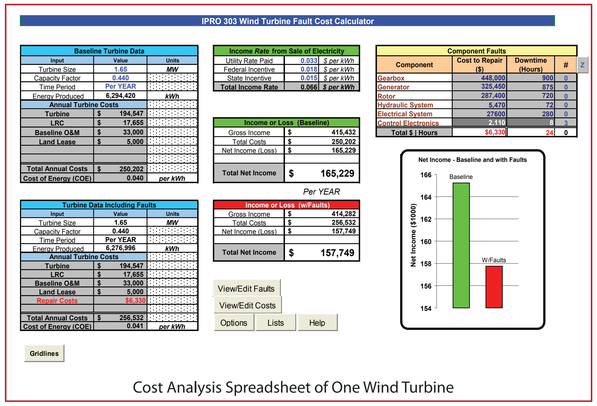
Turbines in a Wind Farm


http://www.facelift.co.uk/images/pic/library/hr-rez/Red-Nose-Windi-Turbine-Bronto-Skylift%20(2).JPG

Turbine Maintenance

Maintenance

- **Unscheduled Maintenance**
  - Occurs when their has been a failure or a detected problem
  - Is expected to occur at some point in a wind turbine's lifetime
  - Even minor failures can shut down an entire wind turbine and require maintenance
- **Scheduled Maintenance**
  - Acts as preventative measure to ensure reliability
  - Refurbishes or replaces old components
  - Equipment is inspected and cleaned
  - Costs vary from locations and resources available
- **Maintenance Procedures**
  - Crews must climb ladders in the tower for as many as 30 stories to access the nacelle for maintenance
  - Expensive cranes are needed to remove and install major turbine components



Cost Analysis Spreadsheet of One Wind Turbine

TEAMS AND TASKS

Teams

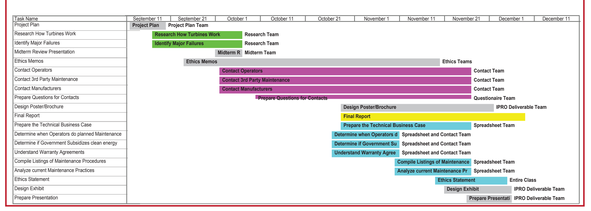
Pre-Midterm Teams

- **Research Team:**
  - *Members: Jesus Cervantes, Samad Erogbogbo, Rob Keane, Kristina Lakiotis, Mithun Michael*
  - Researched how wind turbines work and identifying the major failures
- **Questionnaire Team:**
  - *Members: Sara Claxton, Earl Fairall, Aaron Melko, Viral Patel, Donald Rufatto*
  - Prepared questionnaires for the contact team.
- **Contact Team**
  - *Members: Laolu Adeola, Chris Catalina, Richard Ike*
  - Contacted people in the wind power industry to schedule interviews.

Post-Midterm Teams

- **Team Leaders:**
  - *Members: Earl Fairall, Donald Rufatto*
  - Led the meetings and also helped the teams complete their tasks.
- **Spreadsheet Team**
  - *Members: Jesus Cervantes, Samad Erogbogbo, Richard Ike, Rob Keane, Aaron Melko*
  - Compiled turbine failure data and costs into an interactive spreadsheet
- **Contact Team**
  - *Chris Catalina, Mithun Michael*
  - Continued their work to contact those in the wind power industry.

Gantt Chart



Obstacles

The IPRO team met with difficulties in the following areas:
- Understanding the goals of the IPRO clearly
- Establishing industry contacts and receiving information
- Organizing teams effectively
- Lacking background in wind turbines and business cost analysis
- Taking assertive action to complete tasks
- Document creation and formatting
- Coming together as a team
- Ethical issues with disclosing contacts' names and SmartSignal name

Although the team faced obstacles, many were overcome by:
- Assigning student leadership positions
- Receiving guidance from IPRO professor and sponsor
- Restructuring teams when necessary
- Participating in ethics discussions and creating a non-disclosure policy

Recommended Future IPRO 303 Tasks

- **General**
  - Establish leadership early in the semester..
  - Define a well thought out set of goals.
- **Contact Team**
  - Use previous contact list and keep communication open with contacts.
  - Encourage contacts to participate in live phone interviews.
- **Research Team**
  - Become familiar with the research done this semester and expand on it
  - Find more information on the actual "cost of maintenance".
- **Spread Sheet Team**
  - Enhance the previous spread sheets
  - Combine them into one comprehensive version
  - Apply more research data to the inputs, such as for the maintenance costs