FLORIDA A&M UNIVERSITY - FLORIDA STATE UNIVERSITY
COLLEGE OF ENGINEERING

OPERATIONS MANUAL

Team #12 Offshore Wind Turbine

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1.0 Prototype Components and Assembly

Overview

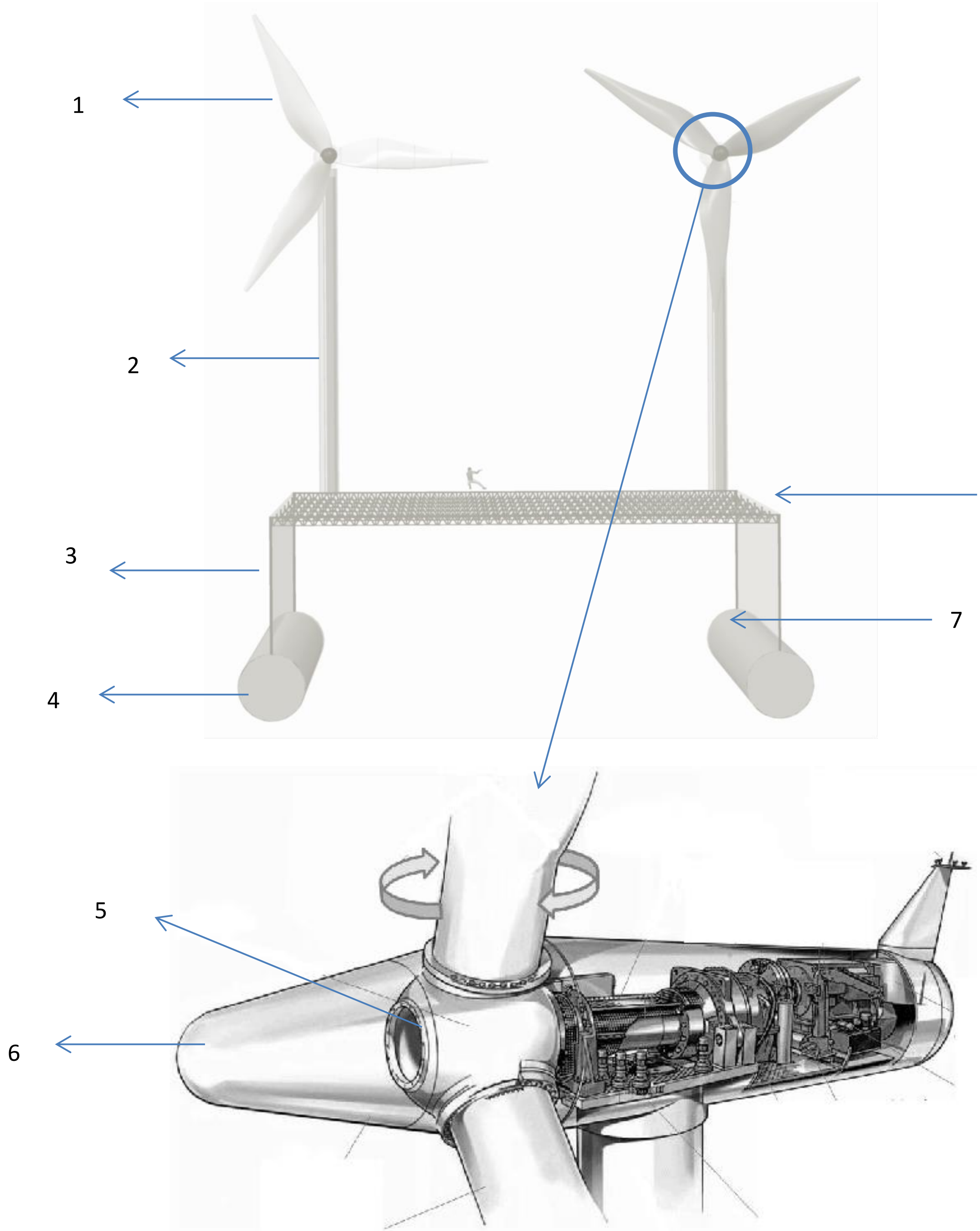

Table 1. Bill of Materials*		
Number	**Item**	**Quantity**
1	Blades	6
2	Turbine Tower	2
3	Truss	2
4	Pontoon	2
5	Hub	2
6	Rotor	2
7	Propulsion Motor	2
8	Deck	1
-	Autonomy Package	1
-	Microcontroller	1

*Autonomy Package, Control System, and Battery not pictured above.

Functional Analysis:

Autonomous System:

There are four main stages of the autonomy package to be installed on the full scale model offshore floating wind turbine: GPS, power stage, controller, and filter stage. The first stage consists of communication between the on land hub and the floating turbine, telling it which route to take. The hardware onboard the floating structure will interpret the controller's instructions. Next is the power stage which is constituted by semiconductor switch arrays made of IGBTs that connect to the motor. In each of the arrays, there are six switches arranged into three pairs. During commission each bridge will be connected to a three phase AC motor, and during operation the motor is closed using delays. Below an insulated gate bipolar transistor is depicted.

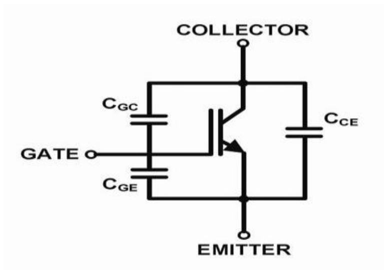

Figure 1. IGBT

The third stage is the controller which physically turns the IGBT switches on ad off at a very fast rate, with capabilities to turn it on and off 32,000 times per second. This controller is made up of two main components: the digital signal processor and the safety processor. The DSP controls torque and charge behavior, while the SP monitors acceleration and the motor currents' consistency. Below is an example of a controller.

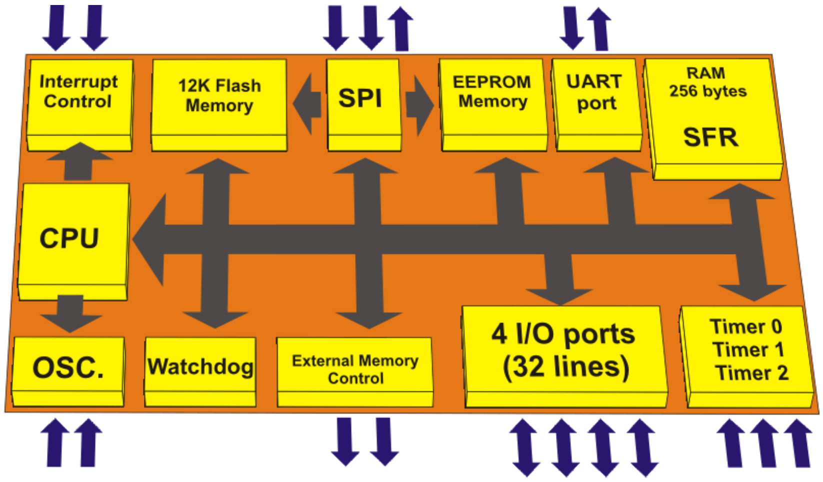

Figure 2. Controller

The fourth and final stage of the autonomy package is the filer stage. This is very important to eliminate signal noise that occurs during operation of the wind turbines. To help filter the noise, inductors are placed in between the transistors to reduce the occurrence of any interference.

Propulsion System

The floating structure will rely on two permanent magnet generators programmed through the Arduino Uno system. Each will have a 100 kW output and require 3m/s start up speed. They were chosen based their rated rotational speed of 50 rpm and survival speed of 40 m/s. The figure below is an illustration of these generators.

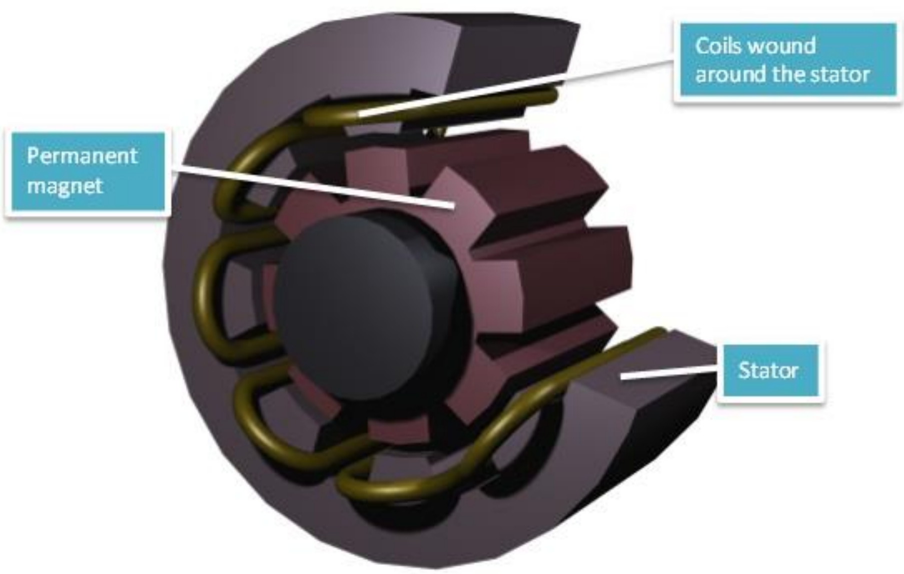

Figure 3. Permanent Magnet Generator

Component Specifications

Turbines:

Turbine: 400 Watt Wind Generator

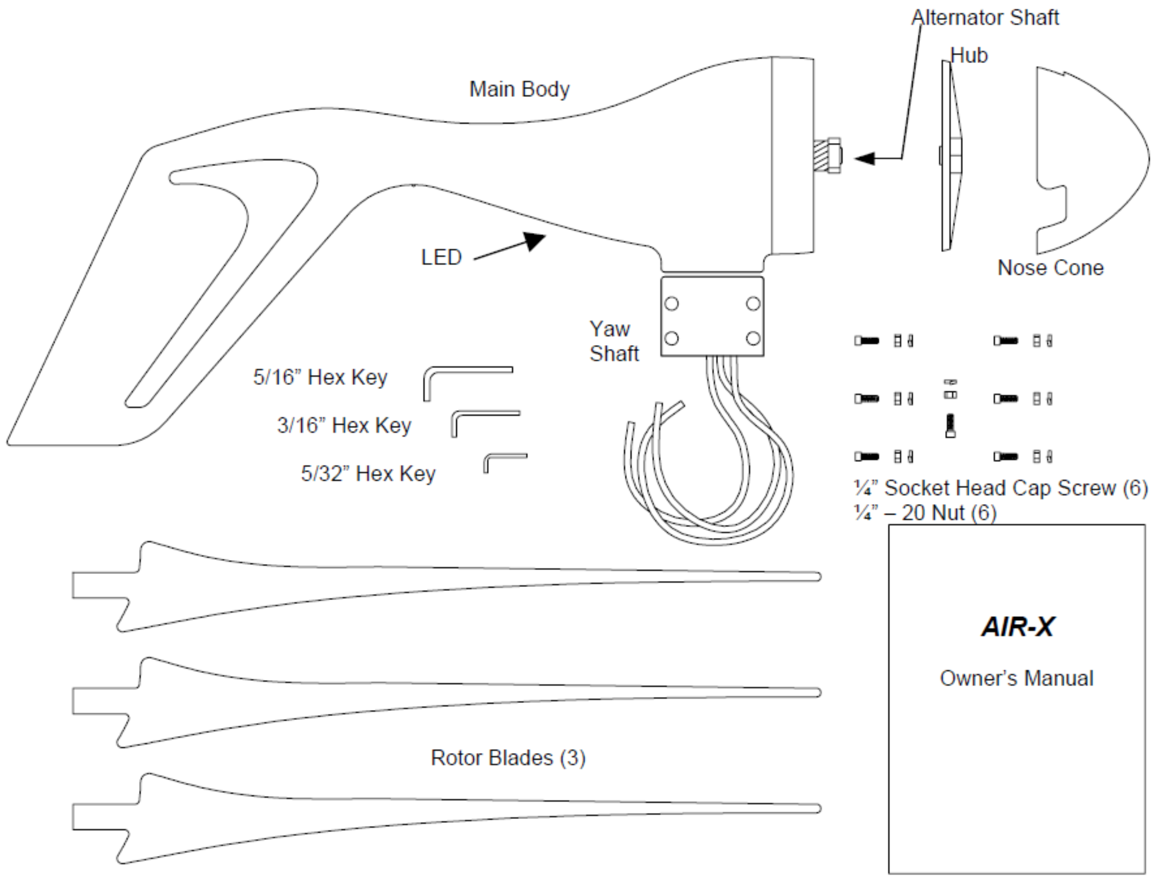

Table 2. Key Specifications	
Weight (lbs.)	
Dimensions (in.)	27" x 15" x 9"
Max Power (in ideal conditions)	19 rpm
Material (blades)	Epoxy Glass and Carbon Fibers
Material (body)	
Rotor Diameter (m)	7
Start-Up Wind Speed (mph)	3 m/s
Rated Power (W)	100
Recommended Fuse Size	

The turbine blades were designed to produce the most power, which is based on interference parameters, such as lift and drag and pitch control. The two illustrations below allowed the group to select the NREL S817 foil shape.

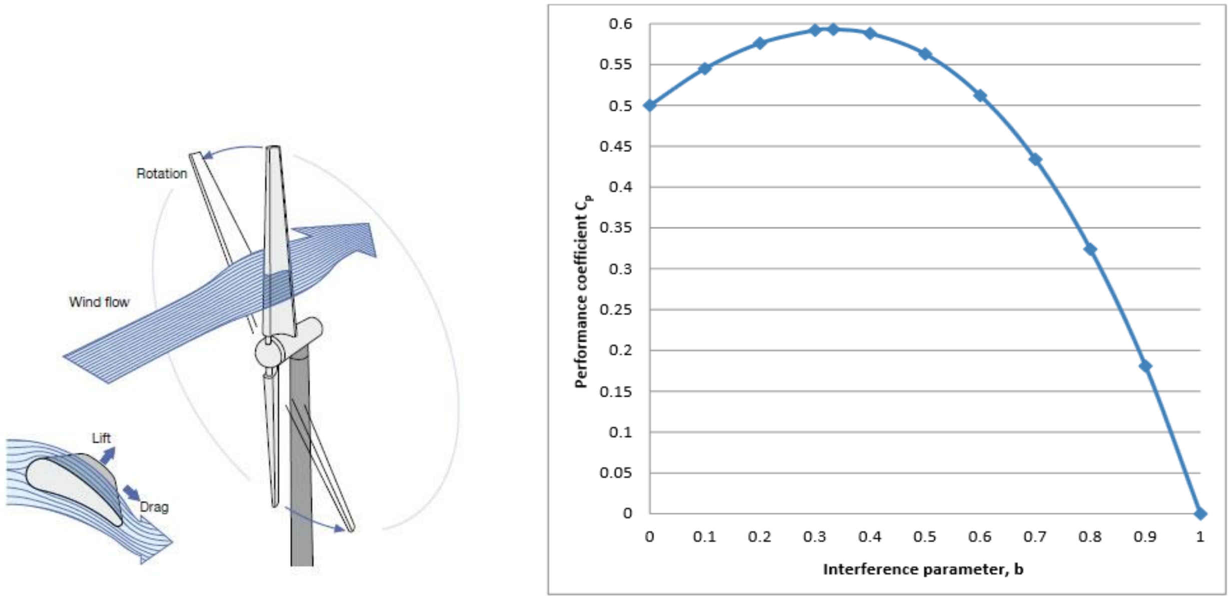

Figure 4. Turbine Blade and Associated Performance Plot

Floating System

Pontoons

Two A618 Grade 1 Steel Galvanized Pontoons, modeled as cylinders

Figure 5. Image of Pontoons

Table 3. Key Specifications	
Characteristic	**Value**
Volume Displaced	590 m^3
Diameter (m)	4
Length (m)	60

The Pontoons will be ballasted to control the buoyancy and conical on the ends for hydrodynamic purposes

Microcontroller

Microcontroller: ATMEGA328P

Table 4. Key Specifications	
Operating Voltage (V)	5
Input Voltage (V)	7 – 12
Digital I/O	14 (6 provide PWM output)
Analog Inputs	6
Memory	FLASH 32 KB, SRAM 2 KB
Clock Speed	16 MHz

Figure 6. Image of the Microcontroller

2.0 Product Specs and Expected Performance

Prior to analyzing and understanding the capability of our scaled down prototype performance, our team was first tasked with providing a product that can be introduced to a market on a full scale basis. The design for our full scale model is shown below in Figure 7. A 100 KW generator will be used to provide the necessary power. The main specifications are shown in the figure below.

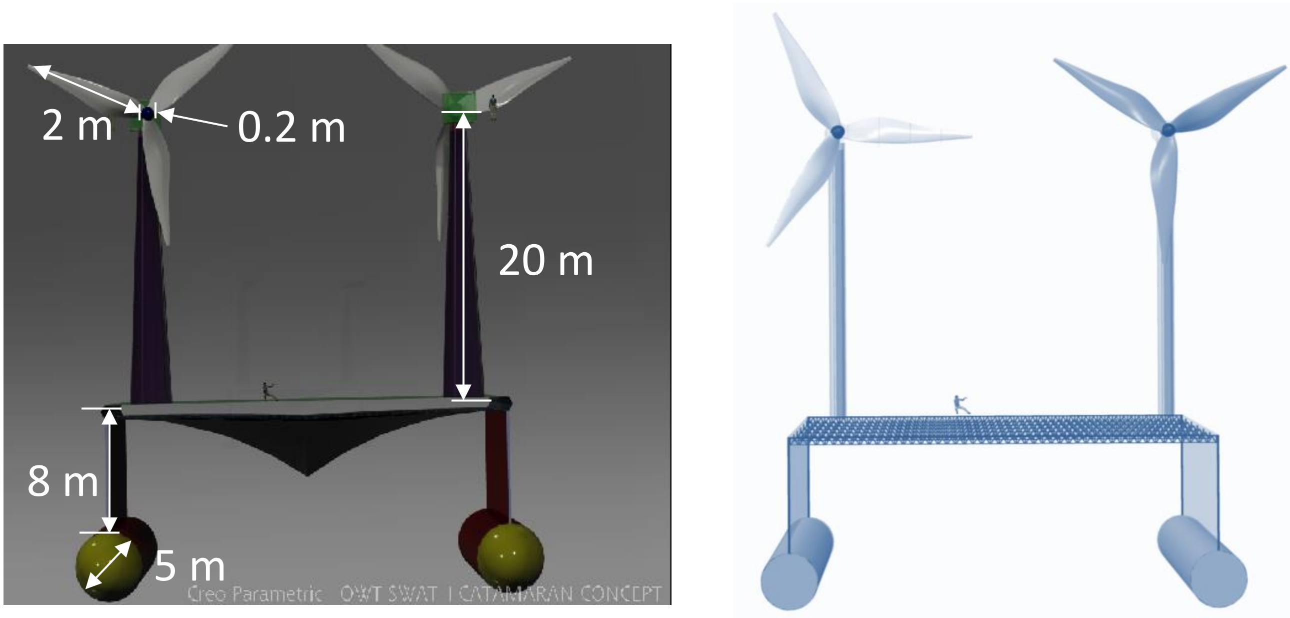

Figure 7. Full Scale OWT Model

The total width, across the entire platform of this model, is about 15 meters. The total depth is about 60 meters. A common and immediate concern that has been brought up by our sponsors and advisors is the cost for material to accommodate these dimensions. However, our research shows that the bigger percentage comes into the construction offshore costs. Along with reducing cost, this full scale model was designed to implement a new innovative product that can used as a selling point to future potential customers. This innovative task, introduced by our sponsors from both the Civil and Mechanical departments, was achieved with introducing an autonomous electrical program using processing microcontroller technology. This technology with be able to using timing delays as well as GPS capability and will be able to program to be able to send the turbine out to our desired location, drop anchor, and be able to remain in once particular location. We expect this technology to be very successful and be a major selling point to future customers. We expect this product to be extremely helpful for many scenarios including providing environmentally sustainable green technology as well as providing a leading power source for communities suffering from weather disasters such as hurricanes and strong tropical thunderstorms. In a general sense, our team has been asked to develop a propulsion system that is able to float and produce power. We are extremely confident that our product can fit these requirements from our sponsor. However, we also wanted to introduce a new type of offshore power generation to existing technologies. Our design introduces something that has not been introduced to real world applications and we feel will be beneficial. By implementing our designs, construction costs as well as maintenance costs will be drastically reduced since both of these steps will be able to be performed on dry dock. Typically wind operations that will produce the maximum power output is about 10 $\frac{m}{s}$. The location that was chosen for this operation is off the coast of the Pacific Northwest, due to the most consistency of offshore wind conditions.

3.0 Standard Operating Procedures

Start and Warm Up

Once the swath has been built on shore it is then operable and awaiting a crisis where instant energy is necessary. Once an event occurs where there is a need for electricity (This product is geared more toward areas that experience hurricanes and need assistance along the coast lines) the autonomous swath is then sent to the location to produce power. Crew members are not necessary since the water craft is autonomous and can not only drive itself to the specified destination but also anchor, and prepare itself to transfer power.

Data Acquisition

Data will be acquired by several different methods according to the type of information needed. There are several different parameters that must be measured at real time such as, location, water depth, wind speed, wind direction and wave activity. Location will be determined using a preinstalled GPS unit. The floating wind turbine will also refer to navigation charts to assure the boat is traveling in safe/appropriate waters such as channels. Sonar will be utilized to determine water depth to ensure the vessel is traveling through areas with adequate depth. Anemometers will be used to determine the wind speed and direction and thus will allow the vessel to orient in a way to capture the most wind to produce the maximum available power. In order to determine wave strength, two different methods will be used. IN order to prepare for high wave activity further ahead in the venture, the vessel will collect data from buoys that provide wave height and intensity. This will allow the vessel to adjust its buoyancy to maintain a stable base by engaging the ballast. The vessel will also have sensors that measure instantaneous wave activity which will then adjust as needed.

Mode of Running

The swath will be powered by duel electric motors that will be controlled by an autonomous platform. Once the vessel has reached its destination and properly orients itself, it will the proceed to engage the turbines 100 kw generator to provide power.

Key Parameters to Demonstrate or Monitor

Key parameters to monitor are location, wind speed, wind direction, water depth, and wave activity. (Please refer to Data Acquisition to see a detailed description of how each parameter is monitored) Stability will be monitored and achieved through two systems. The first is dynamic anchoring which will align the vessel in the desired direction and contain the vessel to a predetermined vicinity. The second is utilizing the ballasting system to raise and lower the center of mass of the SWATH.

Steps for Shutdown

When the area in crisis is no longer in need of power generated by the Floating Wind Turbine, the turbine will then be directed to return “home”. Home refers to the port where the turbine will be housed till it is needed. Once the wind turbine has received this directive, it will then raise anchor, stabilize the turbine blades, adjust the SWATH’s height to optimize speed and then return home. Once home the wind turbine is to be inspected and given a thorough maintenance check. The turbine should be in running order to send out at a moment's notice.

Calibration if Needed

The location of the wind turbine may need to be calibrated depending upon the strength of the GPS signal which hinges upon the number of satellites in the area or if the government degrades the signal. This will take affect areas where limited access and high precision is need. In these instances, the path it may take will heavily depend upon the navigation charts and depth finder. BY utilizing these two pieces of information, the vessel will be able to hone in on the desired coordinates in a safe manner.

4.0 Additional Assembly

Primarily, there are two additional assemblies required to operate the offshore wind turbine. These two assemblies include a drydock and an offshore substation.

Drydock

A drydock is a basin that can be flooded to allow a load to floated in, then drained to allow that load to come to rest on a dry platform. A drydock would be used for the construction, maintenance, and repair of the offshore wind turbine. The ability of our offshore wind turbine to use a drydock is one of the design characteristics that make it unique among the offshore wind turbine industry. It was designed such that it could be constructed in a drydock, that is, on shore rather than offshore. Additionally, because our offshore wind turbine is self-propelled, it can return to shore for routine maintenance or repairs, in a drydock. An example of a drydock can be seen in Figure 8.

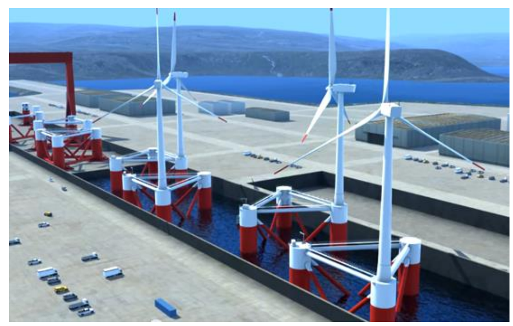

Figure 8. Partially flooded drydock.

Offshore Substation

An offshore substation is a part of the electrical transmission and distribution system that connects the offshore wind turbine to the energy grid. Offshore substations will be required to connect the transmission lines, from the offshore wind turbine, and deliver the electricity generated to shore where it can then be distributed. Offshore substations are especially needed where more than one offshore wind turbine is in use, that is, for offshore wind turbine farms. An example of an offshore substation can be seen in Figure 9.

Figure 9. Offshore substation.

5.0 Trouble Shooting

Primary Potential Problems

- My APM 2 is locking up
- I can't install the Mission Planner
- I can't connect with USB
- I can't connect with Xbee
- I can't connect with 3DR Radios
- My board isn't reading the radio inputs
- The APM board works when it's plugged into the USB, but won't when it's powered by the RC rail
- When I try to compile, I get a stream or errors in red at the bottom of the Arduino IDE window that start like this:
- When I try to compile, I get a different stream of errors in red at the bottom of the Arduino IDE window
- My MUX LED keeps flickering and I'm getting wrong RC readings.
- No GPS lock and board keeps resetting itself.

Solutions to these Possible Problems

My APM 2 is locking up:

The cause is that the data flash card not initializing correctly. To verify this is the problem, take it out and try to power your apm 2 again. You should be able to go through the tests in the CLI successfully. If this was indeed the case put the data flash back in, and power the board up while looking at the terminal screen. It will reformat the card. Leave it plugged in for a 5-10 min, afterwards you should see a "ready" message. You should only have to do this once.

I can't install the Mission Planner:

If you're using Windows XP, make sure you have the Microsoft.net Framework 3.5 installed.

If you get a DirectX installation error that means your copy of Windows doesn't have an updated version of DirectX.

I can't connect with the Mission Planner over USB:

Double check that you've selected the right COM port and baud rate for USB. Also double check in your Windows Device Manager which COM port your APM has been assigned to. It will be listed under Ports.

Did you use the MP installation program, which installs the drivers, and did it complete successfully?

Have you loaded flight firmware to APM?

I can't connect with the Mission Planner over Xbee:

First, remember that you cannot use wireless telemetry with APM 2 while the USB cable is plugged in. Make sure it's unplugged. Check that you've switching the Mission Planner to the COM port assigned to your Xbee that's connected to your PC and set the baud rate to 57600. Ensure that you've gone through the full Xbee configuration process.

I can't connect with the Mission Planner with the 3DR Radios:

Remember that you cannot use wireless telemetry with APM 2 while the USB cable is plugged in. Make sure it's unplugged. Check that you've switching the Mission Planner to the COM port assigned to your 3DR radio that's connected to your PC and set the baud rate to 57600. It should be at least trying to come back home in RTL mode. If it struggles to make it back in a headwind or otherwise being easily blown off course increase Nav_Roll P by 25% until it corrects the problem.

My board isn't reading the radio inputs:

Are you powering the RC pins with an ESC or other 5v source? (You must). If your RC receiver's power LED isn't on, that means the RC rail isn't getting power.

Are you sure the RC connectors are plugged in the right way? Signal wires at the top, ground at the bottom, closest to the board

Is your transmitter on?

Plug a servo into one of your receiver's spare channels and make sure it's working.

The APM board works when it's plugged into the USB, but not when it's powered by the RC rail (ESC/Lipo):

APM allows for both RC power or a separate battery run through APM's built-in power regulator. A solder jumper called SJ1 determines which is used. By default from the factory, that jumper should be soldered which means APM will be powered by the RC rail.

When I try to compile, I get a stream or errors in red at the bottom of the Arduino IDE window that start like this:

ArduPilotMega.cpp:17:24: error: FastSerial.h: No such file or directory
ArduPilotMega.cpp:18:23: error: AP_Common.h: No such file or directory

Solution: You have not put the libraries in the right folder or set the correct folder in the Arduino IDE configuration menu. Make sure to follow the protocol and then restart the GPS systems.

When I try to compile, I get a *different* stream of errors in red at the bottom of the Arduino IDE window that start like this:

C:\Users \Documents\Arduino\libraries\APM_RC\APM_RC.cpp: In function 'void TIMER4_CAPT_vect()':

Solution: Select Arduino Mega as the board type before you compiled/uploaded.

My MUX LED keeps flickering and I'm getting weird RC readings:

If the servos are twitching and not communicating with the hardware. There is a bad PPM encoder firmware in the Atmega328 on your APM board. Please connect warranty department.

No GPS lock, and/or board keeps resetting itself:

Plug the GPS module into the APM board and not the similar connector on IMU shield.

6.0 Routine Maintenance

I. Nacelle-6 months rotation
   a. Generator should be inspected for signs of overheating and burning of the bindings. Magnets should also be inspected for material failure and properly secured. (Note every 5 years magnetic field should be tested and compared to original to make sure still within operation range)
   b. Blades should be inspected for deflection and crack propagation. Also need to be checked for balance. Hub connections may also be a source of failure that should be carefully reviewed and adjusted to maintain correct angles. Gear actuators for pitch should be serviced, lubricated, and inspected at same interval or sooner.

II. SWATH-yearly rotation
   a. Tower, deck, and pontoons should be inspected for corrosion from elements. Special note if operating in salt water as certain materials may be more reactive to these conditions. Welds should also be inspected to make sure they were formed correctly.
   b. Pontoons and motor housing should be inspected for leaks and resealed every couple years.

III. Propulsion
   a. Motor oil should be changed at every port or every 5000 hours of operation. Use of full synthetic is recommended.
   b. Propellers should be inspected for balance and bent/cracked blades.

IV. Electrical Components
   a. Check for burned insulation on all wiring. If detected, look for possible shorts in the circuitry.
   b. All sensors should be calibrated annually and replaced if out of tolerance.

If any signs of fatigue or failure are discovered, notify superior immediately and replace the part before returning to service.

7.0 Key Component Replacement

Due to the innovative autonomous self-propelled design, the maintenance of this offshore wind turbine is minimal compared to its piled counterparts. The most important components that must stay intact are the sensors and motors. The sensors will detect issues and the motors will bring the floating structure back to the dry dock workshop. Onshore pre-commissioning, testing and construction allow for less error and a more reliable wind turbine.

8.0 Spare Parts Required

List of spare parts needed to avoid work/ operation interruption for extended periods of time.

1. Tower – 20m x 0.6m, A616 GradeA steel circular column
2. Decking – 12” x 24” x 1/16”, Aluminum Plate
3. Truss Decking – round 8m HSS 16x0.625 and round 1.2m HSS 5x0.25
4. Floor – Mesh Screen
5. Pontoon – 4m x 60m x 0.0254m Pipe
6. Blades – 9m x (0.9-1.8)m x 0.79mm thick CFRP Propeller
7. Water Props – Propeller
8. Driveshaft
9. Generator – 100kW Permanent Magnet Generator
10. Navigation – GPS
11. Switches – 1” x 1” x 0.25” Silicon IGBT
12. Digital signal processor (DSP)– Arduino
13. Safety processor (SP) – Arduino Sheild
14. Filters – Inductors
15. Microcontroller – ATMEGA328P
16. Wiring
17. Housing
18. Sensors
19. Connections
20. Motor - 300HP Lincoln 1800 RPM three phase TEFC